

STUDIES IN
SMALL-POX AND VACCINATION

WILLIAM HANNA

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BY

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P R E F A C E

THE following studies on the subject of small-pox and its prophylaxis by vaccination have been the outcome of several years of observation of cases which have occurred in the City and Port of Liverpool. Ample opportunity has been afforded for this study from the unique position of Liverpool as a shipping centre, and the great tide of alien traffic which flows through it.

The first and second parts deal with the ever-important problem of the value of vaccination in preventing and mitigating attacks of this dreaded malady, and the inverse relationship of scar-area to severity of attack is pointed out.

The final portion treats of "Concurrent Small-pox and Vaccination": a very interesting and important subject.

It is hoped that the book will appeal to Medical Officers of Health, Vaccination Officers, and those in charge of Infectious Disease Hospitals. In addition, general practitioners may find it useful in furnishing illustrations of cases of small-pox. The work also contains useful and striking diagrams and arguments as to the value of vaccination and re-vaccination which may be used with parents and others who object to these preventive operations.

I am indebted to Dr. E. W. Hope, Medical Officer of Health, City and Port of Liverpool, for much valuable criticism, and to Dr. N. E. Roberts, Visiting Physician, Liverpool City Hospitals, for the loan of some photographs which have enabled me to complete my series illustrating the various points in the text.

LIVERPOOL,
February, 1913.

W. HANNA.

CONTENTS

	PAGES
INTRODUCTION	7-10
PART I.—A STATISTICAL STUDY OF 1,163 CASES OF SMALL-POX, WITH SPECIAL REFERENCE TO VACCINATION IN MODIFYING THE DISEASE	11-26
PART II.—AN ANALYSIS OF 943 CASES OF SMALL-POX (WITH PRIMARY VACCINATION) IN RELATION TO SCAR-AREA AND SEVERITY OF DISEASE	27-34
PART III.—OBSERVATIONS ON THE INTERACTION OF CONCURRENT VARIOLA AND VACCINIA	35-49
CONCLUSIONS	51



STUDIES IN SMALL-POX AND VACCINATION

INTRODUCTION.

A STUDY of the early history of small-pox, before vaccination was introduced, shows that the disease was one of extensive prevalence and great malignancy. In the 18th century it reached its highest point of intensity and distribution in Europe, the mortality from small-pox in England at that period being one-tenth of the total mortality. In London it was constantly present, and the deaths averaged, during the period 1761-1796, from 3,000 to 15,000 yearly; indeed, in the latter half of the century the deaths seldom fell below 1,000. The great malignancy of the disease when introduced into fresh countries in later years has also been frequently recorded. The decrease in small-pox prevalence since the beginning of the 19th century, and the marked reduction in its fatality, have been shown to be due to the protection afforded by the process of vaccination.

There is no subject of medical or scientific interest which has given rise to such controversy as that of the value of vaccination. In the early days of its introduction, Jenner did not stand alone, for Woodville and Pearson, physicians to the Small-pox Hospital in London, made numerous experiments and came to the same conclusion

as Jenner, that the process conferred protection against small-pox. The systematic observations of many qualified observers have, however, long since turned the tide in favour of the upholders of the practice as a scientific and prophylactic measure, and it is unnecessary now to draw attention to the convincing figures which have proved its value. It is sufficient to state that from a long study of the pock diseases of animals, especially vaccinia or cow-pox, and from experiments and observations made by scientists, the relationship of variola and vaccinia has now been established on a firm basis of fact. The experiments of such observers as Thiele, Ceely, King and Hime, and more recently of Klein and Copeman, have shown that it is possible to inoculate a calf with small-pox material and to obtain a vesicle at or near the site of inoculation, identical, or almost so in the first instance, with a human vaccine vesicle. This vesicle becomes even more typical in the case of successive inoculations, and the result is practically the same as if the animal had been inoculated with vaccinia, *for the calf is no longer susceptible to vaccination*. In addition, the lymph from these vesicles has been transferred and used to inoculate successfully human individuals, and the attenuated virus confers protection against human small-pox as ordinary vaccination does.

Small-pox still continues to invade our shores from abroad, the extensive movements of populations, the rapid means of communication, and the travelling facilities afforded by fast steamships, enabling the disease to jeopardize our ports and the country generally, even more so than heretofore. Countries such as Canada, the United States of America, Spain, Russia, Egypt, etc., are well within the incubation period of the disease, and from

time to time persons have been landed in our ports in the incubation stage.

In the interval after a great epidemic, material will gradually accumulate in the shape of large numbers of susceptible children in districts where primary vaccination has not been carried out with strictness, *e.g.*, in the London Metropolitan Unions, where the number of children not finally accounted for (including cases postponed and for which "certificates of exemption" were granted) per cent of total births in the respective years was as follows :—

1893-97	-	-	-	23.9 %
1899-1906	-	-	-	23.5 %
1907	-	-	-	25.8 %
1908	-	-	-	28.8 %
1909	-	-	-	30.7 %

It will thus be seen that, just before an epidemic, a large proportion of children in some large towns may be unprotected by vaccination. In Liverpool the percentage not finally accounted for is comparatively small, being about 5 per cent. Again, those who have escaped the epidemic owing to good vaccination lose some of this immunity as years pass, or in the words of the late Dr. Bond, of Gloucester, "become de-vaccinated" and so provide suitable material for the next outbreak, when the virulence of the disease may succeed in breaking down a comparative insusceptibility.

The liability of a population to a small-pox epidemic therefore may be measured by its density at susceptible ages.

After a long spell (seven years) of comparative quiescence, the disease broke out in epidemic form in Britain in 1902-3; it carried off a large number of persons; in

*Epidemic form
of small-pox*

the City of Liverpool alone there were during that period 2,280 cases, with 161 deaths.

This epidemic of small-pox was extensively prevalent in Europe and America, and the first Liverpool cases were introduced amongst cattle-men from Boston, U.S.A. The disease was raging in Boston, and many cattle-men, employed on cattle boats from the United States, landed in Liverpool; these men were frequently incubating small-pox, and subsequently developed symptoms of the disease in the various lodging-houses of the city. These foci helped on the gradual evolution of the epidemic which was extending over the country. London and other large centres became infected about the same time. In London the disease originated in a Pole, residing in Stepney, who had returned from a visit to Paris; subsequent importations came from Egypt and elsewhere.

The series of small-pox cases under consideration has been collected from amongst those which have been admitted to the hospitals of the City and Port of Liverpool during the past ten years. The large majority occurred during the above-mentioned epidemic period (1902-3), and since then the cases admitted have been chiefly imported from abroad.

All the cases which occurred during the epidemic were not available for the purposes of this investigation, owing to the fact that the method of recording the required particulars was not at first adopted.

PART I.

A STATISTICAL STUDY OF 1,163 CASES OF SMALL-POX, WITH SPECIAL REFERENCE TO VACCINATION IN MODIFYING THE DISEASE.

THE examination of a large series of cases of small-pox is of value as affording additional testimony to the efficacy of vaccination as a prophylactic measure, as an estimate of the severity of the disease, and of the mortality generally in the vaccinated and unvaccinated; and in particular, the measure of the efficiency of the vaccination in the case of the vaccinated. Some new methods have been adopted in recording and comparing this series of cases.

It has been noted from time to time in vaccination records, e.g., those of Russell, Marson, Gayton, and others, that the quality and size of the scar-area have an important bearing on the amount and extent of the eruption, and consequently on the severity of the disease. Attention, however, was only directed to counting the number of vaccination scars, estimating their quality, or approximating their area, and very little has been done to measure accurately this scar-area and to consider its relation to severity and mortality at *different age periods*.

The cases of small-pox numbered 1,163, consisting of 943 vaccinated in infancy and 220 unvaccinated.

The method adopted was that of tabulating the age, the presence or absence of vaccination scars, and in the former case of measuring the area in square inches.

The cases were placed in ten age-groups, and arranged in order to show the proportion of vaccinated and unvaccinated in each. These have been set out in *Tables I* and *II*, where the extent and severity of the disease are also revealed. The influence of vaccination on the mortality will be first considered.

INFLUENCE OF VACCINATION ON THE CASE-MORTALITY.

Whilst there are several criteria of the severity of the disease, such as extent of eruption, temperature, etc., the one of most value is the case-mortality. When, therefore, a comparison is made of the influence of vaccination on the case-mortality of small-pox, it will be seen that amongst the 943 cases which were vaccinated in infancy, there were twenty-eight deaths, or 2·9 per cent, and amongst the 220 unvaccinated cases there were sixty deaths, or 27·2 per cent; that is, the ratio of deaths to attacks is ten times as great in the unvaccinated as in the vaccinated (*see Table II, page 14*).

These percentages are almost identical with Marson's well-known figures, viz., about 8 per cent in those alleged to be vaccinated with or without evidence, and 35·5 per cent for the unvaccinated; these figures are the result of twenty-five years' (1835-60) observations on post-vaccinal small-pox at the London Small-pox Hospital. Dr. Russell's figures for Glasgow (1871-72) were 3 per cent for the vaccinated and 30 per cent for the unvaccinated.

Dr. Woodward, dealing with the last twenty-five years of the 18th century, when all the patients were unvaccinated, states that the death-rate was 32 per cent of the admissions to the Small-pox Hospital. Dr. Gayton's figures for the metropolitan hospitals showed, in the well

TABLE I.
TABLE SHOWING NUMBER OF SMALL-POX CASES (943 VACCINATED AND 220 UNVACCINATED)
AT EACH AGE-PERIOD, WITH RELATIVE DEGREES OF SEVERITY.

	Under 2 years		2-5		5-10		10-15		15-20		20-30		30-40		40-50		50-60		60 and up		Total	
	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.	Vaccd.	Un-vaccd.
A. Modified discrete and discrete	No cases	3	7	3	31	6	54	9	89	1	249	11	163	No cases	63	1	20	2	10	1	686	37
B. Profuse discrete and semi-confluent	No cases	9	No cases	15	3	15	8	19	14	20	77	21	72	5	29	3	13	3	8	No cases	224	110
C. Confluent and death	No cases	17	No cases	8	No cases	5	No cases	3	No cases	9	7	10	13	9	9	6	2	5	2	1	33	73
Total	No cases	29	7	26	34	26	62	31	103	30	333	42	248	14	101	10	35	10	20	2	943	220
Deaths alone	0	17	0	8	0	5	0	1	0	4	3	6	13	8	9	5	1	5	2	1	28	60

TABLE II.

TABLE SHOWING PERCENTAGE OF VACCINATED AND UNVACCINATED CASES RESPECTIVELY
AT EACH AGE-PERIOD AFFECTED WITH SMALL-POX IN DIFFERENT
DEGREES OF SEVERITY.

	Under 2 years		2-5		5-10		10-15		15-20		20-30		30-40		40-50		50-60		60 and up		Total	
	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.	Vaccd.	Un- vaccd.
A. Modified discrete and discrete	No cases	10.3%	100%	11.5%	91%	23%	87%	29%	86.4%	3.3%	74.7%	26.2%	65.7%	No cases	62.3%	10%	57.1%	20%	50%	50%	72.7%	16.8%
B. Profuse discrete and semi- confluent	No cases	31%	No cases	57%	9%	57%	13%	61.3%	13.6%	66.6%	23.1%	50%	29%	35.7%	28.7%	30%	37.1%	30%	40%	No cases	23.7%	50%
C. Confluent and death	No cases	58%	No cases	30.7%	No cases	19%	No cases	9.7%	No cases	30%	2.1%	23.8%	5.2%	64.3%	9%	60%	5.8%	50%	10%	50%	3.6%	33.2%
Percentage case-mortality vaccinated and unvaccinated	—	58%	—	30.6%	—	19%	—	3.2%	—	13.3%	.9%	14.2%	5.2%	33.3%	8.9%	50%	2.8%	50%	10%	50%	2.9%	27.2%

and imperfectly vaccinated, a case-mortality of from 3 to 9 per cent, whilst it reached over 40 per cent in the unvaccinated, and in various other places it was just as high.

The small-pox of the last decennium has been of a fairly mild type. The question of age distribution in the population attacked, and the country of origin of the disease, may have an important influence in determining the virulence of an epidemic.

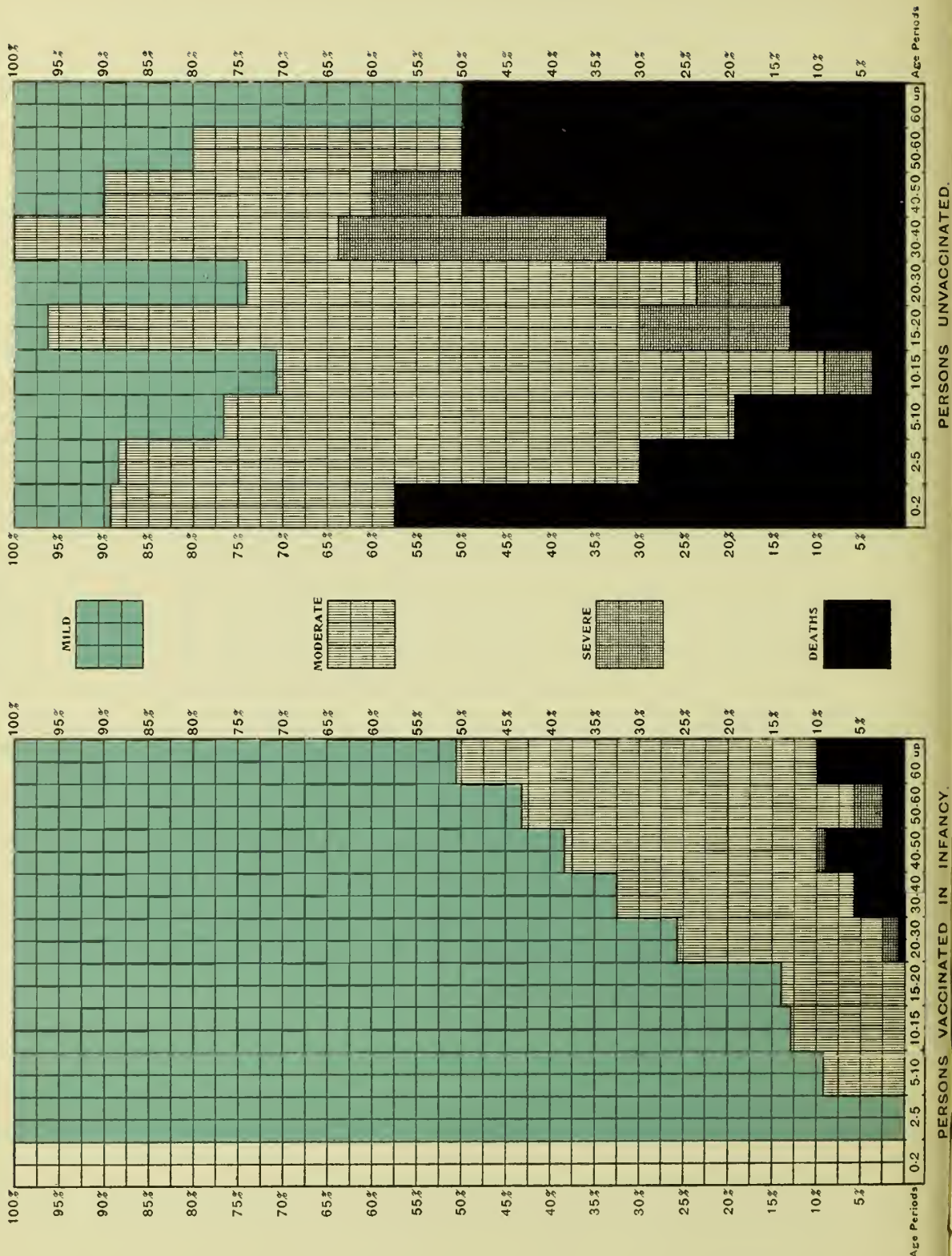
On the *Chart A* (pages 16, 17) and in the accompanying tables, the cases have been arranged into suitable age periods, so as to show clearly the value of vaccination on the mortality in passing from infancy to adult and old age. An examination of the deaths recorded amongst the vaccinated under each age-group reveals the interesting fact that no death occurred until the 20-30 year group is reached, and the case-mortality for this group is only 0.9 per cent. It will be observed, however, that the percentage case-mortality amongst the vaccinated steadily rises from this point onwards in life, but never exceeds 10 per cent.

On contrasting these figures with those amongst the unvaccinated, we observe a striking difference. Under 2 years of age the deaths are 58 per cent of the cases attacked, for 2-5 years 30.6 per cent, and the figure then falls until 10-15 years, when it is 3.2 per cent.

This decrease may be attributed to the gradual development of the natural resistance and recuperative power of youth enabling the patient to recover from the disease; this may be compared with what is observed in other infectious diseases. From adolescence onwards the mortality in the unvaccinated gradually increases, until it reaches 50 per cent at the periods from 40 years and upwards. This high ratio of deaths to attacks amongst

CHART A. SMALL-POX IN LIVERPOOL DURING TEN YEARS 1902-1911.

Showing the Relative Severity of the Disease as it affects Vaccinated and Unvaccinated persons, based on the Records of 1,163 Cases



EXPLANATION OF CHART A.

PERSONS VACCINATED IN INFANCY.

1. There are no cases of small-pox under two years of age.*
2. The great majority of persons attacked have the disease in a mild form.
3. There is a gradual loss of vaccination immunity as age advances.
4. No deaths occur until after the twentieth year of life.

PERSONS UNVACCINATED.

1. Many cases occur under two years of age, and a large proportion of these are fatal.
2. There is no influence controlling the fatality of the disease, except the recuperative power of youth, as shown between the ages of 10 and 30 years.
3. Deaths are very numerous in children under 10 years, and in persons over 40 years of age.

Contrast the absence of cases below two years of age in the left-hand diagram, with the same columns in the right-hand diagram.

* See footnote, page 31.

the unvaccinated, especially at the early and late periods of life, compares with what is well known of this disease in pre-vaccination days, viz., that the severity and mortality lay heaviest on infants and young children under ten years of age. The large excess of births and rapid accumulation of susceptible persons in the growing manufacturing towns afforded ample material for an epidemic to feed upon; therefore the number of adults and old people who had escaped the disease in pre-vaccination days was few. At the present time, when an epidemic spreads over the country, in addition to the unvaccinated children, the disease also attacks those adults who have never been vaccinated in their youth, and in addition, the power of recovering from small-pox decreases as age advances.

THE INFLUENCE OF VACCINATION ON THE ERUPTION; AND ON THE SEVERITY OF THE DISEASE.

The amount of eruption on the body of a patient affected with small-pox always gives one an opportunity to form an opinion of the severity and probable fatality of the case.

The eruption may be divided into five categories, and commencing with the very mildest, these are as follows: modified discrete, discrete, profuse discrete, semi-confluent, and confluent. For purposes of easy examination they have been grouped with the descriptive terms as follows:—

A.—Modified discrete and discrete, representing the mild types of the disease.

B.—Profuse discrete and semi-confluent; a moderate type of severity.

PLATE I



A MILD AND MODIFIED CASE OF SMALL-POX

Patient well vaccinated in infancy, the scar area approximating one square inch. Age twenty-five years. Note the mild character of the eruption, which is, as usual, chiefly confined as regards distribution to the face and extremities. The usual freedom of the triangle of the neck from eruption is to be noted.

PLATE II



A CASE OF SMALL-POX OF MODERATE SEVERITY

Patient vaccinated in infancy. Re-vaccinated successfully six days before eruption appeared. Age twenty-four years. Note that in this case the rash is more profuse than in *Plate I*, but the distribution is the same. The anterior triangle of neck is relatively free. The re-vaccination is well shown, and there is a characteristic crop of small-pox vesicles situated on the inflammatory areola around the vaccination site. Photo taken on fifth day of rash.



PLATE III



A WELL-MARKED CASE OF SMALL-POX OF SEVERE CHARACTER IN A MAN WHO HAD NEVER BEEN VACCINATED UNTIL AFTER INFECTION WITH SMALL-POX

Patient unvaccinated in infancy. Vaccinated for first time seven days before onset. Age twenty-two years. Note the severity of the case, the size of the pustules, and distribution of the eruption, more marked on face and extremities than on body. The vaccination has been successful, and without doubt saved the man's life; he recovered completely. Photo taken on ninth day of eruption.

C.—Confluent or very severe ; to this last category have been added those in which death occurred.

There are therefore three types of severity, viz., *A* mild, *B* moderate, and *C* severe (see *Plates I, II, and III*).

Let us examine the eruption and severity at different ages, as it occurs in the natural disease, i.e., in the unvaccinated (see *Chart A*, page 16).

An examination of the column under 0–2 years of age shows that over 58 per cent of the cases at this age period are found with the fatal kind of small-pox, 31 per cent with the medium type, and only 10 per cent with the mild form of the disease ; the same is also the case for the period 2–5 years, showing the marked incidence of the severe kind on unvaccinated childhood.

Contrast in *Chart A* the severity of the disease and mortality under 10 years of age in the unvaccinated with the similar columns in the vaccinated.

The middle period of life has a lower percentage of severe cases ; this may be explained by the higher resistance of the body and power of recovery, which gradually increase up to 30–35 years of age ; this natural resistance is well shown in the unvaccinated in *Chart A*.

The number of cases of moderate severity continues high in the unvaccinated throughout life, but as age advances, the very severe type again appears.

The dark-shaded portion in the chart indicates the mortality limit amongst the severe cases ; and it will be observed that from 10 years onwards to 40 years many severe and confluent cases recover. Compare this with the severe cases followed by death in children under 10 years and in old people, that is, at the extremes of life.

I. *Influence on the Extent of the Eruption.*

The effect of vaccination is to reinforce the natural immunity of the body. When it does not prevent the onset of the disease, it may either influence the extent of the eruption or modify the character of the individual papules. Let us consider first the influence of vaccination on the extent of the eruption. On contrasting in *Tables I* and *II* and *Chart A*, the primarily vaccinated cases under the different age-groups, a distinct series of facts will become apparent. In the first place, there are no cases recorded under 2 years*, and only seven cases under 5 years; the latter, moreover, were exceedingly mild in character and characterized by very sparse eruptions, a few papules only appearing in isolated parts of the body. Again, only three cases of moderate severity appear under 10 years of age, and of the severe type no cases are recorded under 20 years. When the columns of vaccinated persons in *Table II* are contrasted, it will be seen that the percentages of persons with the different forms of the disease are graduated: the highest percentages in each age group are found to have the disease in a mild form, the next highest in moderate form, and so on; the most severe cases show the lowest percentage and only appear after 25-30 years of age, and the deaths occurring in this period are comparatively low.

On the total cases of all ages amongst the vaccinated, the percentages are 72·7 of mild type, 23·7 moderate, and only 3·6 of a severe character.

The protection afforded by vaccination against attacks of the disease is therefore well seen in this investigation, where no cases of small-pox in the vaccinated are to be found under 2 years of age* (*see pages 13, 14, 16*), that is,

* See footnote, page 31.

in the years immediately following upon the process of vaccination.

II. *Influence in Modifying the Character of the Specific Eruption.*

The eruption of unmodified small-pox usually passes through a well-recognized series of changes.

The first appearance of the eruption takes place approximately three days after the onset of symptoms, as red spots about the size of a pin's head, first seen chiefly on the forehead and wrists. They cannot be felt as distinct spots above the skin, and disappear on pressure. Shortly after, they swell into raised pink papules, fairly hard and easily perceptible to the touch; they grow in size and can frequently be recognized as "shotty," but this depends on their position in the skin and the tension of the contents due to effused fluid. After a day or so, when they have become, in typical cases, rounded and defined, vesiculation develops, and at the beginning of the third day the papules have become vesicular. These vesicles are loculated, and if pricked, the clear contents will escape in small amount. The loculation is due to trabeculæ running through the interior which divide the pock into several compartments. These vesicles gradually become opaque or grey in colour, and the contents become pustular; this happens about the sixth day of the eruption, and by the eighth, ninth, or tenth day they begin to dry up, with the formation of crusts. This is the typical course in all cases except those of a severe or hæmorrhagic character. In cases modified by vaccination, various interesting changes may be demonstrated in the character of the eruption.

The following modifications in the eruption due to

vaccination have been noted in the series under examination.

1. The papules have been numerically few in number and limited to isolated parts of the body. They have, however, gone through the typical course of evolution.

2. The rash has been profuse, but the lesions were superficially placed; the vesicles or pustules were frequently small or irregular in size, and owing to their superficial position were unilocular, like vesicles in chicken-pox; in some cases they evolved quickly, and suppurated early and imperfectly.

3. The papules, owing to wart-like masses of granulation tissue formed at the base, appeared as raised fleshy elevations.

4. A concurrent vaccination might cause rapid inspissation of the pustules, the crusts dropping off early.

In the accompanying *Plate IV*, the first type is well illustrated; the rash is very sparse, the papules passing through the various typical stages as in natural small-pox, attaining full size. The type described under No. 2 is well shown in *Plate V*, where the rash is very profuse, but the individual lesions are much smaller than those occurring in natural small-pox, the pustules varying in size from a pin's head to a pea within a small area; they are superficially placed in the skin, and the eruption has passed through to suppuration quickly and imperfectly. In this respect it is well known that the rapidity of evolution of a papule varies with its size and the depth of its situation in the skin, and the photos show the effect of the vaccination in bringing about this condition.

Another type illustrated, *Plate VI*, shows a modified eruption which is known under the name of "wart-pocks." These pocks are chiefly found on the face, and consist of

PLATE IV



A MILD AND MODIFIED CASE OF SMALL-POX INFECTED, SIX DAYS
BEFORE BIRTH, FROM ITS MOTHER

The child was born in hospital and successfully vaccinated on the same day. Age fifteen days. Note the few and scattered papules on this infant, the modified character is due to the successful vaccination which was done six days before onset of disease. Photo taken on the seventh day of eruption.

PLATE V



MODIFIED CASE OF SMALL-POX, SHOWING IN THIS CASE A NÆVOID CHARACTER OF A CONCURRENT VACCINATION

Patient vaccinated in infancy. Re-vaccinated on the day of appearance of eruption. Age twenty-six years. In this case of small pox the rash is profuse but extremely modified, the papules vary much in size, are superficially placed, maturing rapidly and irregularly. (A) Superficially placed and rapidly maturing papules. Photo taken on ninth day of rash.

PLATE VI

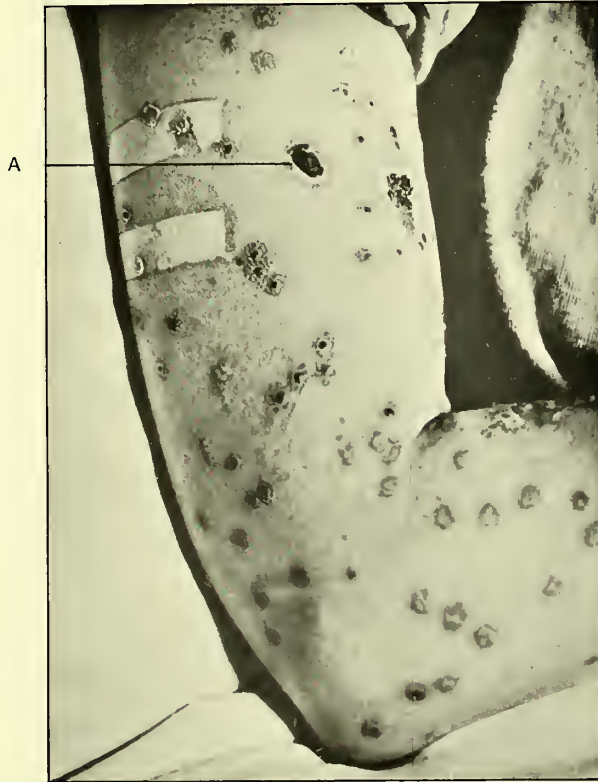


A WELL-MARKED CASE OF SMALL-POX. SHOWING CONDITION
OF "WART POCK"

This type of case, although somewhat repulsive in appearance, is nevertheless fairly mild in its character, and permanent disfigurement or pitting rarely follows.



PLATE VII



A SEVERE CASE OF SMALL-POX, NOT VACCINATED
BEFORE INFECTION.

Patient unvaccinated in infancy. Vaccinated on the day following the appearance of the rash. Age thirty-four years. The case shows the effect of a concurrent vaccination on the course of the disease, a rapid pustulation and drying up of the rash. (A) Atypical vaccination scars with aborted vesicle and yellow crust. The clear areas around each scar are not vesicles, but white or pinkish areas left by the retraction of the scab. Photo taken on the thirteenth day of rash.

papules raised by the formation of wart-like masses of granulation tissue; the papules have a fleshy base, and frequently the suppurative process is shortened, the pocks being surmounted by a yellow pustule about the size of a pin's head, which soon dries up, pitting is rare.

Frequently, a vaccination when performed after the date of infection, or even after the onset, has the effect of hastening the maturation and desiccation of the pustules. For example, *Plate VII* shows a patient, unvaccinated in infancy, who developed small-pox with a sudden and violent onset and profuse rash. Vaccination was performed on the day following the appearance of the rash, but in spite of this it was thought the course of the disease would prove to be severe. Suppuration set in about the usual time. When the pustular stage ought to have reached its height, however, and the patient would have been in a most critical condition, the temperature fell, the pustules at once began to inspissate and form crusts, and then rapidly fell off. The patient was free from crusts in an incredibly short time. This rapid passage through the pustular and desiccation stages was undoubtedly due to the vaccination.

Ricketts regards vaccination as having a double effect on the course of the disease: one effect is an influence on the extent of the rash, or the numerical severity; the other is in the direction of modifying the eruption. As age advances he regards these two faculties as waning together, but "the protective influence against numerical severity goes quicker, and the faculty to cause an eruption to be modified is retained for years after the other is wholly lost."

These points are well illustrated in the series of photographs which accompany this paper.

DE-VACCINATION.

The length of the period of protection can be fairly well gauged by an examination of the appended Tables.

The period will vary a good deal for each individual, but from the figures given, the highest resistance lasts only a short time. After a few years those who become susceptible develop the disease only in a mild form, and further on in years greater severity manifests itself in the type of the disease, but no cases of severe and fatal small-pox appear in this series of cases until over 20 years of age. It is evident, then, that following a primary vaccination in infancy, the period of greatest protection in childhood probably does not cover more than three to five years, and after this, the absolutely preventive efficiency of vaccination rapidly diminishes, and cases of small-pox begin to appear amongst the vaccinated. The power to modify the disease, however, still continues to remain considerable until adolescence, and even into later life, as will be seen by comparing the severity and the percentage case-mortality in different age-groups of vaccinated and unvaccinated cases.

The rapid loss of vaccinal immunity following on primary vaccination in infancy is probably to be explained by the rapid changes going on during growth in childhood. The experience of those who have done much vaccination in adolescents or adults shows that the protection afforded to adults by re-vaccination lasts much longer than the same operation in children. It is well known that this restored protection again diminishes, but much more slowly.

An instructive example of this gradual loss of protection was shown in six members of a family (a mother

and five children) admitted to hospital suffering from small-pox. The disease attacked them all in varying degrees of severity. They all showed evidence of having been vaccinated in infancy: each of the children had only one vaccination scar, of $\frac{3}{8}$ square inch in area; the mother had three vaccination scars, each of the same size.

Case	Age	Number of Scars.	Scar-area	Character of Disease	Remarks
1	4 years	1	$\frac{3}{8}$ sq. inch	Modified discrete, very mild	Papules very few, not over 7-8, and not vesicular.
2	7 „	1	ditto	ditto	ditto.
3	9 „	1	ditto	ditto	Papules few, more numerous than in cases 1 and 2, not vesicular.
4	12 „	1	ditto	Modified discrete, mild	Papules very numerous, became vesicular but soon dried up.
5	15	1	ditto	ditto	ditto.
6	37	3	$1\frac{1}{8}$ sq. inch	Discrete	Eruption more marked than in the children, and passed through the characteristic stages.

This series shows the gradual loss of the modifying power in the vaccination as age advances, and it is interesting as shown in the same family, the vaccination scar-area being the same in each case except in the mother, whose scar-areas were much larger, and therefore her protection showed a proportionally larger degree of modifying power. Where age has advanced sufficiently to eliminate the

previous vaccinal protection, it will be found that the disease reverts to its original type, as seen in the unvaccinated. In many cases, however, the immunity conferred in infancy may persist in some degree until late in life, especially in its power to modify the disease. This gradual loss of immunity is well shown in the vaccinated, in *Chart A* (page 16), where as age advances the mild cases become fewer in number, and later in life the severe types of the disease, with deaths, begin to appear.

PART II.

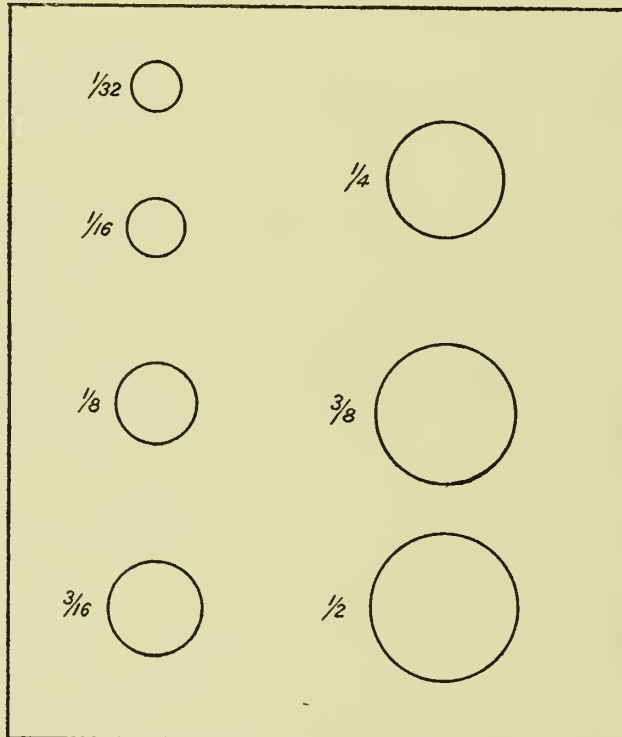
AN ANALYSIS OF 943 CASES OF SMALL-POX (WITH PRIMARY VACCINATION) IN RELATION TO SCAR-AREA AND SEVERITY OF DISEASE.

THE beneficial effects of vaccination are to be experienced especially in those cases where the process has been carried out in a thorough manner, and we may conclude that where vaccine lymph has been inserted in several places it is more effectual than when inserted in one place only, i.e., the larger the local manufactory of immunity or the greater the quantity of the specific material inserted, the greater the degree of the resulting protection.

Accordingly, the amount of immunity may be reckoned by the superficial area of the scar.

An analysis of the above-mentioned 943 cases of small-pox, which had been primarily vaccinated, was carried out to test the point. The scar-area was recorded for each vaccinated case of small-pox on admission to hospital, according to the method referred to in the circular letter of the Local Government Board of England, issued in 1902. The diagram (on *page 28*) represented the area of the scars in square inches, and was used to estimate it rapidly, and to record it. This method of recording superficial area is a much better one for estimating the relationship of immunity to mortality and severity, than that of counting the number of scars, as was done in the valuable series of Dr. Marson and others.

The scar-areas were arranged into age and severity groups; an average scar-area was also obtained for each age period; this grouping of scar-areas into severity and age groups has proved a most important one, and some



SCAR-AREA DIAGRAM OF THE LOCAL GOVERNMENT BOARD.

new facts have come to light regarding the changes which scar-areas undergo.

A glance at the figures in *Table III* will illustrate clearly the arrangement in relation to severity and age.

The severity groups are the same as those used in the examination of the previous set of small-pox cases in Part I.

TABLE III.

TABLE SHOWING AVERAGE SCAR-AREA IN SQUARE INCHES AMONGST 943 VACCINATED CASES
OF SMALL-POX, CLASSIFIED ACCORDING TO AGE-PERIOD AND SEVERITY OF DISEASE.

	Under 2 years	2-5	5-10	10-15	15-20	20-30	30-40	40-50	50-60	60 and up
Modified discrete and discrete ..	No cases	.25	.42	.51	.59	.96	.78	.45	.42	.35
Profuse discrete and semi-confluent ..	No cases	No cases	.62	.53	.52	.88	.66	.47	.41	.30
Confluent and death	No cases	No cases	No cases	No cases	No cases	.50	.54	.40	.28	.18

TABLE IV.
A.—AVERAGE SCAR-AREA OF 943 VACCINATED CASES OF SMALL-POX
UNDER DIFFERENT AGE-GROUPS.

	Under 2 years	2-5	5-10	10-15	15-20	20-30	30-40	40-50	50-60	60 and up
Average scar-area in square inches ..	No cases	.25	.43	.51	.58	.93	.73	.45	.41	.32

B.—AVERAGE SCAR-AREA OF 368 VACCINATED PERSONS TAKEN FROM AMONGST THE
GENERAL POPULATION WHO HAVE NOT HAD SMALL-POX.

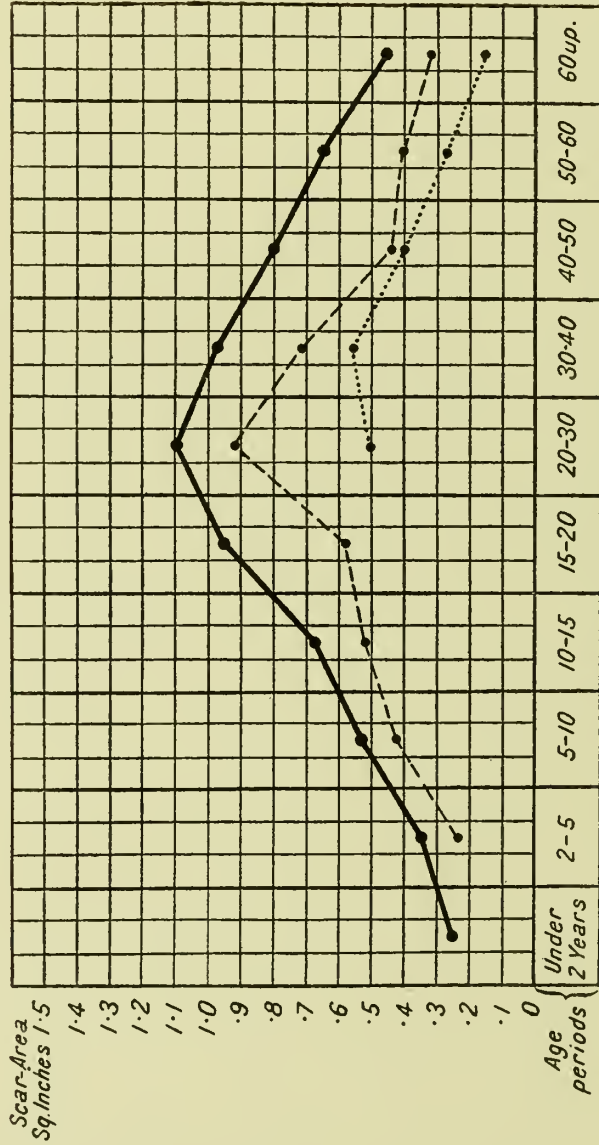
	Under 2 years	2-5	5-10	10-15	15-20	20-30	30-40	40-50	50-60	60 and up
Average scar-area in square inches ..	.25	.35	.53	.69	.96	1.1	.98	.80	.67	.47

In the early years of life it is striking, as previously stated, to find that under two years of age no cases of small-pox are found amongst those who have had a primary vaccination in infancy,* from 2-5 years only very mild cases, and from 5-20 years no severe cases of small-pox, or deaths, have occurred. In the remaining years of life, it is interesting to observe that in almost every age group the mildest types of the disease (modified discrete and discrete) are those with the largest average scar-area; those with moderate or severe types of the disease (profuse and semi-confluent) have a slightly smaller scar-area, at least in mid-age periods; and in those with the most severe types of small-pox, or where deaths have occurred, the scar-area is the smallest (see scar-area diagram, *page 32*). It would be well to note that it is a difficult matter to lay down a standard of severity for each group of cases, especially of the mildest types. The general impression created by the extent of the eruption being the only guide, cases on the border line are difficult to locate, and when the cases in any group are comparatively few, the more difficult it is to attain absolute accuracy.

It is clearly evident, however, that the scar-area of the vaccination bears an inverse relation to the character of the eruption and intensity of the disease. An examination of *Table IV, A*, will show the average scar-area for all the cases at each age-period. It is striking to notice the gradual increase in this scar-area until 20-30 years, and following on this, a gradual decline in the size of this area as years advance.

* I do not here include cases of small-pox in infants (see chart and photographs at the end) who have been vaccinated for the first time *after infection* with the disease, and have been in many cases born in a small-pox hospital. These are included amongst "concurrent cases," which are dealt with in Part III. as a separate class.

DIAGRAM: SCAR-AREA AMONGST VACCINATED POPULATION AND
VACCINATED CASES OF SMALL-POX.



This point has proved of some interest, and an attempt has been made to explain it. It was thought that in early life, and up to 20 years, those persons who had larger areas than those recorded escaped small-pox. As the primary vaccinal immunity, however, gradually faded, these persons came under the influence of the disease, and the recorded scar-area of the small-pox cases increased.

This supposition, however, ought to hold good and to extend into old age ; this it does not do, and it will therefore not explain the steady fall which takes place from 30 years onwards.

On reviewing the figures it becomes more probable that the increase in the scar-area is due to stretching of the scar tissue on growth of the body, reaching its height at the period 20-30 years, and as age advances this scar cicatrix begins gradually to atrophy and fade. This seems clearly borne out by the figures, in the tables and in the diagram opposite.*

In order to test this matter still further a measurement was made of the scar-areas of a certain number of the general population who have never had small-pox.

The persons whose measurements were taken were those found in some of the infectious-disease hospitals, where the majority were children ; a further series was obtained in the Liverpool Workhouse, where persons of middle and advanced age were examined.

In all, the scar-areas of 368 persons, who never had small-pox, were measured. The figures in *Table IV, B* (page 30), and the diagram opposite, show the result. It will be evident that there is a gradual increase in scar-area

* The suggestion of this explanation was made by my colleague, Dr. Stallybrass.

in each age-period, from .25 square inch under 2 years of age, to 1.1 square inch at 20-30 years of age: this is the highest average reached; the area then gradually falls away in size until at 60 years it is .47 square inch. This gradual increase until 20-30 years and then a gradual decline is a matter of some importance, and is fully substantiated when we consider that in all, including small-pox cases, the scar-areas of 1,311 persons have been measured.

Another interesting point to observe is that the curve formed by the average vaccination scar-area of the general population which is shown on the attached diagram, is a higher one at all age-periods than that obtained from those who have been attacked by small-pox. This is another point in favour of the value of large vaccination areas in protecting the individual from the disease.

In many previous investigations on the influence of scar-area on small-pox, the cases with the scar-areas of approximately the same size have been taken and grouped, and shown to be associated with varying degrees of severity; but no account seems to have been taken of the age of the patients, nor was the interesting fact realized that the scar-area in the individual varies at different periods of life. In future comparisons this point will have to receive more consideration.

PART III.

OBSERVATIONS ON THE INTERACTION OF CONCURRENT VARIOLA AND VACCINIA.

It has been abundantly shown by the experiments of Thiele and Ceely, and more recently by Klein and Copeman, that cow-pox or vaccinia may be considered as an attenuated descendant of small-pox; and in connection with this close relationship, if not absolute identity, of these two affections, the examination of the following series of 75 cases of small-pox with a concurrent vaccination will prove of interest. The cases have been collected during the past ten years in the City and Port of Liverpool. Many of them were persons who were landed incubating or suffering from the disease, and were removed to the Port Isolation Hospital; these were chiefly cattle-men from Boston, who landed incubating small-pox during the severe outbreak in that city in 1902-3.

The cases may be examined in the light of the relative effects produced on one another by each of these conditions: (1) As regards the success of the vaccination when performed subsequently to infection with small-pox; and (2) As regards the effect of the vaccination on the course and severity of the disease. Cases of concurrent variola and vaccinia have rarely been given the prominence which they deserve, and it was with this object that the present series was collected. The series, then, gives information of the effect of *vaccination or re-vaccination*

performed after exposure to infection and running *concurrently* with the course of the disease.

THE SUCCESS OF THE VACCINATION.

The success of the process may first be considered, and the series may be conveniently divided into two groups, viz.: (1) Those who have never been vaccinated until infected with small-pox, *Chart B* (page 37); (2) Those who have been primarily vaccinated in infancy, *Chart C*. (page 38).

On examining the charts it will be seen that the period of twelve days has been taken as the duration of the incubation period: this has been found to be practically correct for all the cases; they were all carefully investigated both as to the symptoms of onset and initial rash, and found to correspond to the period set forth in the charts.

It cannot be disputed that possibly cases may occur with a day or so longer or shorter incubation period, but very few of this sort can be quoted as evidence for an incubation period other than that stated. The average generally accepted and acted on for public health administration is twelve days, a period which has been found to work out well in practice, the rash appearing about three days after initial symptoms.

The first point to notice in connection with those cases is that all have been exposed to the infection of small-pox, and all with two exceptions (*see Chart B*), have contracted and developed signs of the disease. These two exceptions were cases of children born in hospital of variolous mothers, vaccinated within 24 hours of birth, and were under daily observation (*see Plate VIII*).

PLATE VIII



MOTHER SUFFERING FROM SMALL-POX NURSING HER
SUCCESSFULLY VACCINATED BABY.

Mother aged twenty-five years. Vaccinated in infancy. Baby born in hospital and successfully vaccinated on the following day. No signs or symptoms of small-pox appeared in the child, which was nursed by the mother throughout her own illness in hospital, and discharged after six weeks. (A) Infant's successful vaccination. Photo taken on the ninth day of the vaccination.

CHART B.
CONCURRENT VARIOLA AND VACCINIA.
Cases unvaccinated before infection with Small-pox.

No.	Probable Day of Infection	DAY OF DISEASE ON WHICH VACCINATION WAS PERFORMED																			SEVERITY OF DISEASE			REMARKS
		INCUBATION PERIOD											ONSET			RASH			MILD	MODERATE	SEVERE			
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17				18	19	
1	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	No	Development	-	A few papules
2	-	V	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	A few papules
3	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	Papules few and scattered
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	A few papules—face, arms, legs, &c.
5	-	-	V	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	A few papules
6	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Very few papules
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
9	-	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
10	-	-	-	-	-	V	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
11	-	-	-	-	-	-	V	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
12	-	-	-	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
15	-	-	-	-	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
16	-	-	-	-	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
19	-	-	-	-	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
20	-	-	-	-	-	-	-	-	-	V	-	-	-	-	-	-	-	-	-	-	-	-	-	Death
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Death
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Death

V — Successful Vaccination. A — Unsuccessful Vaccination.

CHART C.
CONCURRENT VARIOLA AND VACCINIA.
Cases with Primary Vaccination before infection with Small-pox.

No.	Probable Day of Infection	DAY OF DISEASE ON WHICH RE-VACCINATION WAS PERFORMED																			SEVERITY OF DISEASE			REMARKS
		INCUBATION PERIOD											ONSET		RASH			MILD	MODERATE	SEVERE				
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16				17	18	19	
1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	Six or seven papules A few papules
2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	Thirty or forty papules Ten or twelve papules
3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	Few papules Few papules
4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	Only a few papules Few papules
5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
13	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
15	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
16	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
17	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
18	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
19	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
21	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
22	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
24	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
27	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
31	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
32	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
33	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
34	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
35	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
36	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
37	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
38	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
39	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
40	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
41	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
42	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
43	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
44	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	
45	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	X	-	-	

V—Successful Vaccination. A—Unsuccessful Vaccination.

The cases have been set out showing those vaccinated and re-vaccinated on different days: first, during the period of incubation, and second, after the onset of symptoms, and even until three days after the rash had appeared. It is unnecessary to say that vaccination efficiently performed in susceptible people before exposure to infection of small-pox will, almost without exception, prove successful, and will protect the individual from developing any symptoms or signs of the disease.

Vaccination during Incubation.—On examining the charts it will be found that all the vaccinations and re-vaccinations have been *successful if performed during the incubation period* and even up to the day of onset of symptoms. When the term “successful” is used, it must be understood that the phenomena at the site went through the typical and normal course of human vaccination. These phenomena may be shortly described as follows: a slight inflammatory reaction may appear at the site, but nothing of moment occurs until the end of the third day, when firm, flat, elevated papules appear at the site of the operation; these become surrounded by a halo of hyperæmia. Vesicles appear on the fifth or sixth day, and are especially marked at the periphery. These are filled with clear lymph, and the zone of hyperæmia has increased, with acute swelling; the vaccination is red and firm, and the axillary glands may be swollen. Cloudiness begins to appear in the vesicles on the eighth day, and subsequently they become opaque and yellow. The height of the vaccination is reached on the ninth or tenth day, and from this date there are signs of rapid desiccation. The changes most characteristic of vaccination are found during the third, fourth, fifth, and sixth days.

The *successful* vaccinations and re-vaccinations

— allow 14 days
before.
See p 47

recorded in the charts were therefore more or less of the above-described characters, and they all showed the characteristic ring or vesicle situated on a papule and going on to suppuration and desiccation. (*See Plates IX and X.*)

Vaccination after onset of the disease.—The operations performed subsequently to the onset of symptoms were unsuccessful (*see Plates XI, and XII*). The papule did not reach its typical character, the areola may not have developed and vesicles did not appear, or the vaccine pocks developed a nævoid character or appeared stunted in development, and rapidly dried up. It must be granted, however, that in some of the cases the organisms introduced into the system may have had some modifying effect on the course of the disease, although no typical reaction occurred. This point will be referred to later. In other cases, and notably in those vaccinated late in the disease, no reaction appeared at the site, or simply a slight traumatic reaction occurred. It will be well to mention at this point, that fallacious conclusions may be drawn from the appearance of the vaccination area under the following conditions. It is well known that an especially abundant eruption is not infrequently observed on parts of the body which, before the eruption appears, have been affected by mechanical or inflammatory irritation (*see Plate XIII*). Such areas of eruption are sharply marked off, and take on strikingly the form of the area of irritation, e.g., a patient who has been previously carrying heavy bags on his back will show a more profuse eruption on his shoulders, or the irritation in the front of the neck caused by a collar stud will cause a little crop of vesicles to appear at this point. Other examples might be mentioned, such as an eruption round the thigh where a garter has caused pressure,

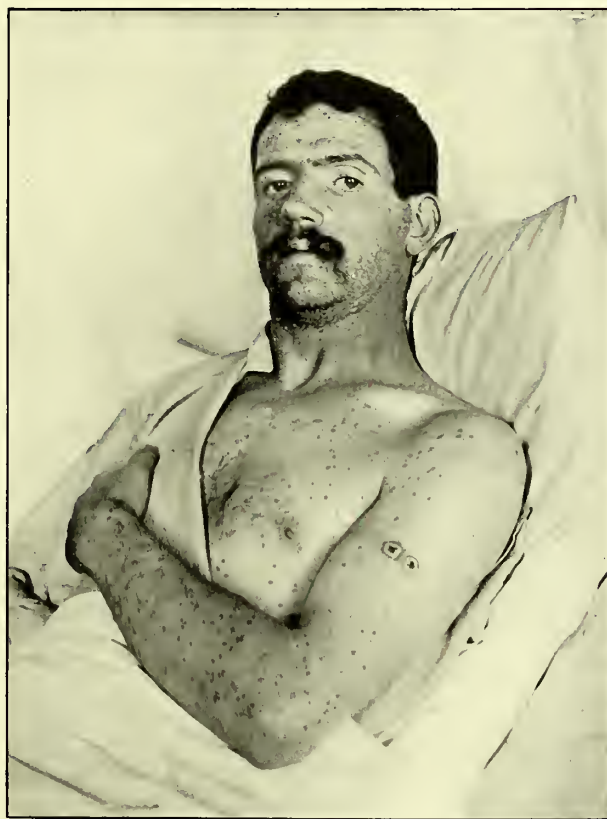
PLATE IX



A VERY MILD AND MODIFIED CASE OF SMALL-POX

Patient vaccinated for the first time seven days before onset of symptoms. Age seven years. The successful vaccination has modified exceedingly the disease, so that the papules are comparatively few in number. This boy was infected by his sister, who was unvaccinated, and had a most severe attack of small-pox. Photo taken on the sixth day of rash.

PLATE X



A MODIFIED CASE OF SMALL-POX

Patient vaccinated in infancy. Re-vaccinated four days before onset of disease. Age twenty-six years. This patient shows a successful re-vaccination which is typical in appearance.

PLATE XI



A MILD AND MODIFIED CASE OF SMALL-POX

Patient vaccinated in infancy. Re-vaccinated on the day after onset of symptoms. Age twenty-four years. This patient shows a vaccination which is atypical in character.

PLATE XII



A SEVERE ATTACK OF SMALL-POX IN A PERSON WITHOUT
PRIMARY VACCINATION IN INFANCY

Patient unvaccinated in infancy. Vaccinated for first time on the fourth day of the disease. Age twenty-seven years. The plate shows that the eruption, as shown on the upper arm, was very profuse over the body; the vaccination having been performed rather late was atypical and naevoid in character. Photo taken three weeks after the appearance of the rash.

PLATE XIII



A VERY MODIFIED CASE OF SMALL-POX

Infantile vaccination did not take. Re-vaccinated successfully six days before onset. Age twelve years. This case is interesting as showing that the inflammatory areola around the vaccination area has determined a numerous crop (A) of small-pox vesicles to appear. The rash is well marked and confined more particularly to the face. Photo taken on the sixth day of the rash.

PLATE XIV



A CASE OF SMALL-POX OF MODERATE SEVERITY

The patient was a Russian immigrant, and had been very poorly vaccinated in infancy, the scar-area only approximating one-tenth square inch. He remained critically ill for a long time, but ultimately recovered. Aged seventeen years. A scratch on the right hand caused by the patient breaking a pane of glass has determined a confluent crop of papules to develop on each side of the scratch. (A) Confluent crop of vesicles at scratch.

PLATE XV

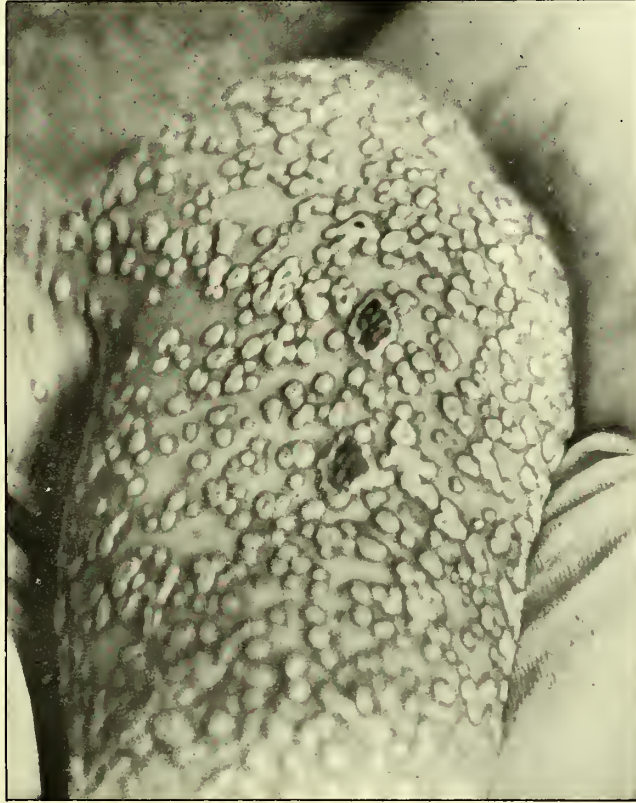


A

A MILD AND MODIFIED CASE OF SMALL-POX

The patient was vaccinated in infancy. Re-vaccinated without result five days after onset of the disease. Age twenty-five years. A confluent eruption is seen on the forehead, due to spirit compress used by the patient to relieve headache. The patient was vaccinated five days after onset of the disease without any local result. (A) Unsuccessful attempt at vaccination. Photo taken on fifth day of the rash.

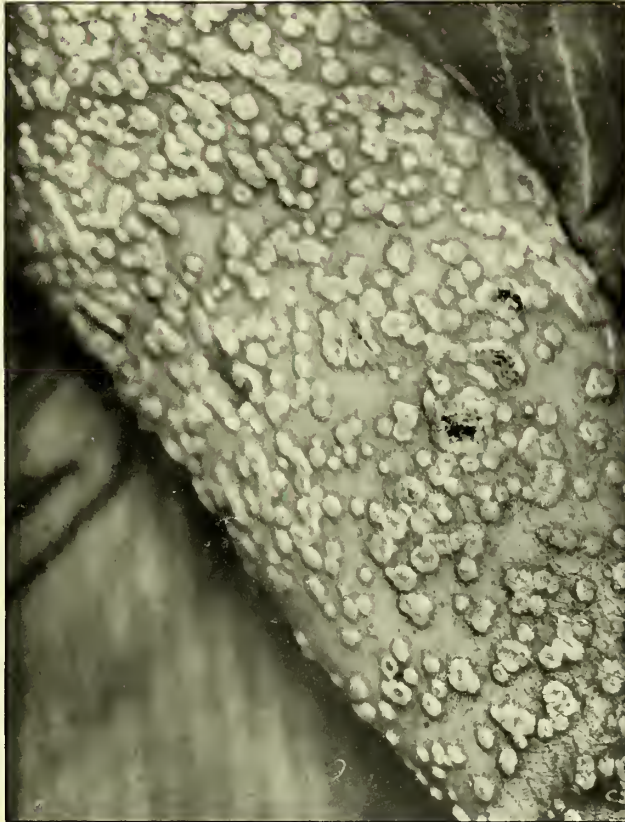
PLATE XVI



A SEVERE CASE OF SMALL-POX

The patient was vaccinated in infancy. Re-vaccinated without result five days after onset of disease. Age thirty-five years. The case shows that the disease may become very severe in those who have lost immunity with advancing years: this patient is ten years older than that shown in *Plate XV*. The result of vaccination was atypical and of a nævoid character. Around the areas are irregular rings of confluent small-pox vesicles and pustules, which give an erroneous appearance of success. Photo taken on the eighth day of the eruption.

PLATE XVII



A SEVERE CASE OF SMALL-POX. UNVACCINATED IN INFANCY

The patient was vaccinated for the first time unsuccessfully three days after onset of symptoms and after the appearance of the rash. Age forty-three years. The result of the vaccination has been unsuccessful, and the appearance of the vaccination areas compares with *Plate XVI*. Photo taken on the sixth day of the eruption.

or a confluent eruption on each side of a scratch on the hand (*see Plate XIV*). Similar phenomena can be seen after chemical or other irritation (*see Plate XV*).

When a vaccination has been performed, therefore, from the day of onset onwards until the rash appears, the inflammation and irritation due to the operation and the slight local reaction which occurs may cause a crop of small-pox vesicles to appear around the area. This is especially the case in severe or confluent small-pox, but may be also seen when the rash is very sparse on the rest of the body. These vesicles, especially in severe cases, may coalesce so as to form a ring around the vaccination site, and give rise to a false appearance of success of the operation (*see Plates XVI and XVII*). Many cases, therefore, said to be successfully vaccinated, are really due to coalescence of small-pox vesicles and pustules around the area of the vaccination. This, I am convinced, is the case; it is only likely, however, to give rise to doubt in cases of severe or confluent small-pox where the eruption is profuse.

Clinical Society's Report.—These observations were completed, when attention was drawn to a report, published in 1878, of a Committee of the Clinical Society of London, formed to investigate the periods of incubation, contagiousness, etc., of small-pox. In this report there are twenty-two cases of concurrent variola and vaccination recorded by Dr. Birdwood, of the Metropolitan Asylums Board's Hospital. These cases are incomplete in their details, but I have taken twenty of them which can fairly well be used in comparison. These have been arranged in the same type of chart as that of the present paper, and it is surprising to find a very close agreement (*Chart D, page 42*).

It will therefore be abundantly evident from the

CHART D.
CASES OF CONCURRENT VARIOLA AND VACCINIA (DR. BIRDWOOD).

No.	Probable Day of Infection	DAY OF DISEASE ON WHICH VACCINATION WAS PERFORMED																			SEVERITY OF DISEASE		REMARKS																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																														
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V—Successful Vaccination.

A—Unsuccessful Vaccination.

W—Doubtful Vaccination.

Z—No Rash.

} Apparent success due to irritation and inflammation at site of vaccination

charts and photographs that the operation of vaccination performed at any time during the incubation period will be successful. This may be true even during the first period of onset, but if carried out subsequently to the initial symptoms, the vaccination will not be successful or typical in its appearance. Dr. Birdwood states that he has "only found one vaccination which was successful if vaccinated on the day of eruption or after." In my opinion, and for the reasons which have been given, the case was probably not a successful one, the appearance of success having been given by the coalescence in a confluent case of the vesicles and pustules around the inflammatory zone of vaccination. In the same report, Dr. Colclough, who was at that time Assistant Medical Officer at the hospital ships, in a note states, "In the few instances in which I have vaccinated patients on their admission, when the eruption has been in the macular or papular stages, the re-vaccination has failed, and the reports of over fifty cases of re-vaccinations (taken from the case books), in various stages of eruption, coincide with my few instances."

I have often heard the statement made by medical men, that when persons have been vaccinated and the operation is not proving successful, there is a likelihood they will develop small-pox, or that these cases ought to be watched and isolated. In my opinion it is in cases recently vaccinated which show evidences that the operation will probably be successful, and where there is low immunity, that small-pox is likely to develop; these cases require to be kept under surveillance. Some time ago, a vessel arrived in Liverpool having had a case of small-pox on the voyage; the man died and was buried at sea five days before reaching Liverpool. All the crew were vaccinated on arrival; one of them, who assisted in burying

this man, developed a very mild rash of small-pox ten days after vaccination and the arrival of the ship ; his vaccination had taken in three places, and showed typical vesicles and other associated signs. Therefore, assuming that the vaccinations have been properly performed with active lymph, the cases to be watched more particularly are those which show signs of the vaccination "taking."

INFLUENCE OF CONCURRENT VACCINATION ON THE COURSE OF THE DISEASE.

Another aspect of the subject may now be studied with advantage, namely, the influence of this vaccination on the course and severity of the disease (*see Charts B, C, and D*). p 37, p 38

p. 42 The degrees of severity have been classified for convenience into three groups : Column 1 represents a *mild* attack of the disease ; Column 2 a *moderate or severe* attack ; and the *very severe* group is recorded under Column 3 : this group also includes deaths, but these are shown individually in the body of the table.

Chart B.—On an examination of the thirty cases without a primary vaccination in *Chart B*, it will be seen that of Cases 1 to 5, vaccinated within the first three days of infection, two developed no symptoms or signs of the disease, whilst three had an exceedingly mild attack after an initial malaise. In these latter only a few papules appeared, which never became vesicles, but simply died away ; in these aborted cases the small-pox had just overcome the protective effect of the vaccination.

the 14 days before see p 37 Tracing the cases further on in the disease, we find that the type becomes more or less severe, according to individual susceptibility, until we come to those of

moderate severity, vaccinated from the seventh day of infection up to the onset; following on this the cases vaccinated after the onset of the disease will be seen to have been of the very severe type, three of them ending fatally, showing that cases vaccinated at the stage of onset and after the rash has appeared, have much less chance of benefiting by the vaccination.

Chart C.—If attention be now turned to *Chart C*, showing forty-five cases of small-pox with a primary vaccination in infancy, it is of interest to find that in this group the effect of the *primary* vaccination is shown on the course of the disease: the primary vaccination along with the re-vaccination performed concurrently has greatly assisted in modifying the severity of the disease.

Further, it will be noticed that in this chart of cases which show a primary vaccination, there are no cases found vaccinated on the day of infection or on the first three days following. This may be accounted for by the fact that the double vaccination, i.e., primary and re-vaccination, has prevented the onset of symptoms or appearance of rash in persons re-vaccinated on these days, and therefore I have been unable to obtain small-pox cases to place on the chart in the position corresponding to these days; this view is also supported by the chart of Dr. Birdwood's cases. It may be remarked, however, that the number of cases is small to draw such final conclusions; still, I draw attention to the fact as being one of probably some importance from an administrative standpoint.

On examining the cases re-vaccinated before the onset of symptoms, it will be seen that in nearly all the disease was of a mild or very mild type. Taking this portion, i.e., during incubation period, of the series in *Chart C*, there are only four cases out of twenty-seven in which the

9 2

eruption may be considered as of moderate or severe character.

The cases vaccinated after the onset of the disease, and subsequently to the appearance of the rash, showed a more pronounced type; in this case most of the patients had the disease in a moderate or severe form.

When it is stated that the vaccination or re-vaccination was unsuccessful as an operation, it must not be understood that the modified organisms implanted in the system did not exercise any appreciable modifying effect. Case No. 28 amongst the unvaccinated (*Chart B*) illustrates this point. A lady, unvaccinated in infancy, contracted small-pox abroad, and was vaccinated one day after the appearance of the rash; a slight traumatic reaction occurred at the site of vaccination, with ill-defined papule and aborted vesicle, forming a yellow crust, which was quite atypical. The case passed through a severe attack; towards the twelfth to fourteenth day of the disease, however, when the suppurative stage ought to have been at its height, it was surprising to find the pustules rapidly drying and falling off, so that within a day or so they had entirely gone; the resulting scars were totally absent, and only marked staining remained, which disappeared under a year, and no trace of the disease can now be seen after some years. The case was, to my mind, a convincing proof of the value of vaccination done subsequently to onset of symptoms, and the operation ought therefore to be performed on all cases admitted to hospital. Other cases, not so striking, can be quoted.

The remarkable antagonism of these two diseases can only be explained by a consideration of the question of immunity or concurrent immunities. It may suffice to say that in small-pox with a concurrent vaccination, it is a

race between the virulent and the modified organisms ; the less virulent and the more saprophytic forms grow faster and produce immunity more quickly than the more virulent ones. Protection is not acquired at any particular time, but there is a gradual accumulation of immunity in the blood, which usually shows itself to be completed by the beginning of the second week after vaccination. ||

It would seem from an examination of the charts, that nine days after vaccination is the period required to give real evidence of the increasing protection against small-pox. — but 14 days.

It is therefore evident that the intensity of the disease bears an inverse ratio to the period of vaccination ; the later the disease appears after vaccination, the more opportunity for the vaccination to be successful and develop its counteracting immunity ; when the small-pox appears early in the course of a vaccination, the more severe is the course of the disease.

On referring to *Chart B* of unvaccinated cases, it will be seen that cases of small-pox vaccinated within three days after infection will develop very slight or no symptoms of small-pox ; and a reference to *Chart C* shows no cases occurring within the first three days. One may safely infer, therefore, that vaccinations performed within the first three days of infection in persons with a primary vaccination will not develop small-pox, and in those who are unvaccinated the chances are that the disease will not develop ; or, in other words, vaccination requires nine days to develop an immunity which will absolutely prevent or minimise an attack of small-pox. — 14 days

CONCURRENT CASES AMONGST INFANTS.

An instructive series of concurrent cases is shown in the following *Chart E*, with its accompanying photographs. The series sets out in tabular form seven cases of *small-pox in infants* with concurrent vaccination. The majority of these were born in hospital of variolous mothers, and vaccinated within a few days of infection; two are shown to have been infected in utero.

It will be seen that *Cases 1* and *2* (*Plates XVIII and XIX*), infected with small-pox on the day of birth and the day following respectively, were vaccinated within twenty-four hours, with entire absence of development of any symptoms or signs of the disease; and the mothers continued to nurse these children until they were convalescent and discharged; in these cases the vaccinations were entirely successful and absolute protection was afforded.

Cases 3 and *4* (*Plates XX and XXI*) were vaccinated later in the incubation period of the disease. *Case 3* was vaccinated at the end of the third day of incubation, and had a very mild attack, as illustrated in the photograph. The eruption was very sparse and scattered, and the individual papules rapidly passed through the preliminary stages to pustulation; this is one of the characteristic effects of vaccination. *Case 4* was vaccinated on the fourth day of incubation, and had a very mild attack.

Case 5 (*Plate XXII*) was vaccinated on the fifth day of incubation, the day following its birth, and showed a more profuse eruption of small-pox. This baby was infected in utero. The mother's rash appeared on December 12th, while the child's eruption appeared on December 27th, exactly fifteen days later.

Case 6 (Plate XXIII), four months old, and unvaccinated, was infected with small-pox on March 30th; owing to various circumstances in connection with the illness of the mother and consequent delay in the reporting of the case, the baby was not vaccinated until the eighth day after infection; the eruption was profuse, but complete recovery took place.

Case 7 was a baby infected on February 28th in utero. The mother's rash appeared on that day; the child was born on March 6th and vaccinated on March 9th. The disease was of very severe type and death ensued. The vaccination in this case was carried out too late to have an opportunity of neutralizing or modifying the course of the small-pox.

Without undue repetition of perfectly obvious facts, it will not be out of place to again point out that the non-development of small-pox or its extraordinarily mild character in those infants of the above series which were vaccinated in good time, contrasts markedly with what is shown in *Chart A* (*page 16*), as occurring amongst unvaccinated children, where a 50 per cent mortality is shown as a result of the neglect of this obvious precaution.

Fortunately it has been possible to insert two plates (*XXIV* and *XXV*), which will bear out the above observation and serve as contrasts with the foregoing series.



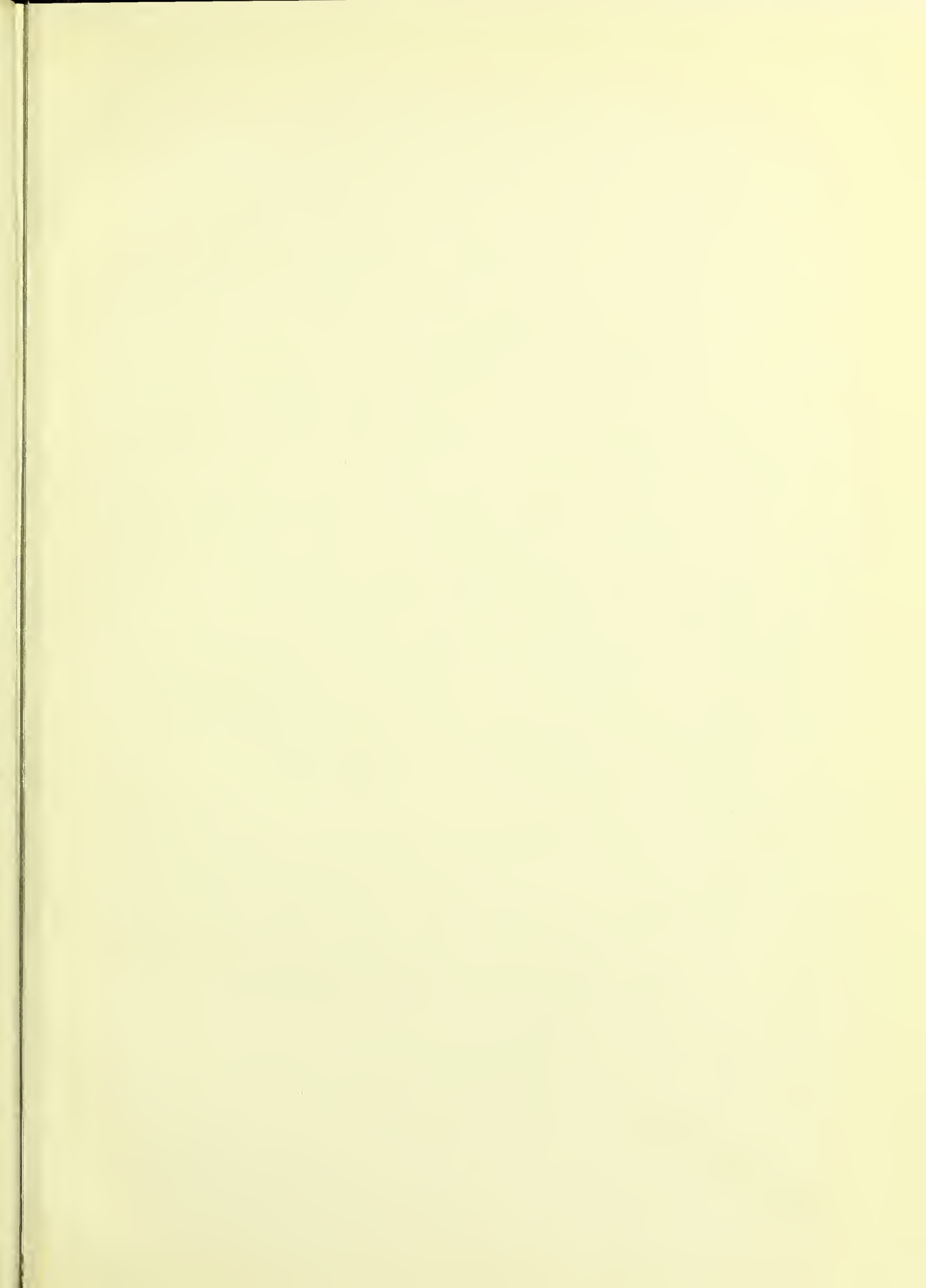
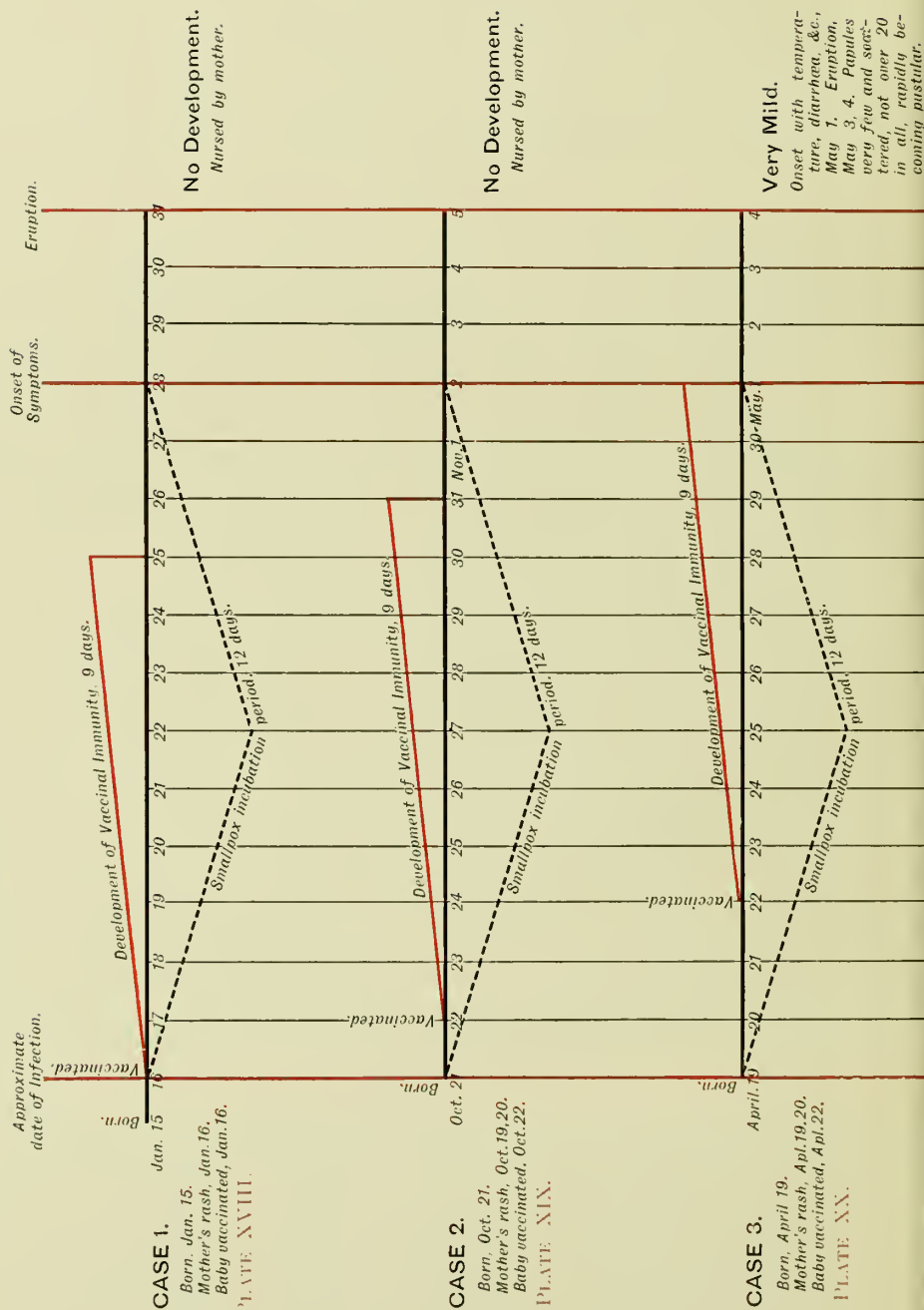


CHART E.

CONCURRENT VARIOLA AND VACCINIA

As seen in the following series of SEVEN INFANTS, showing the effects of Vaccination when performed on certain days during the incubation period.

(Prepared by DR. HANNA.)

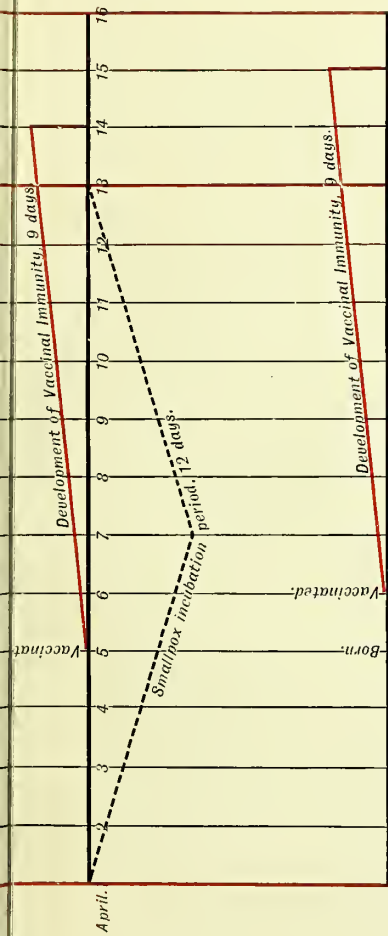


CASE 4.

Aged 3 months.
Infected, April 1.
Vaccinated, April 5.

PLATE XXXI.

Very Mild.
Onset, April 12.
Eruption, April 15.
Papules few, 8 or 9
on face, about 20 on
body.

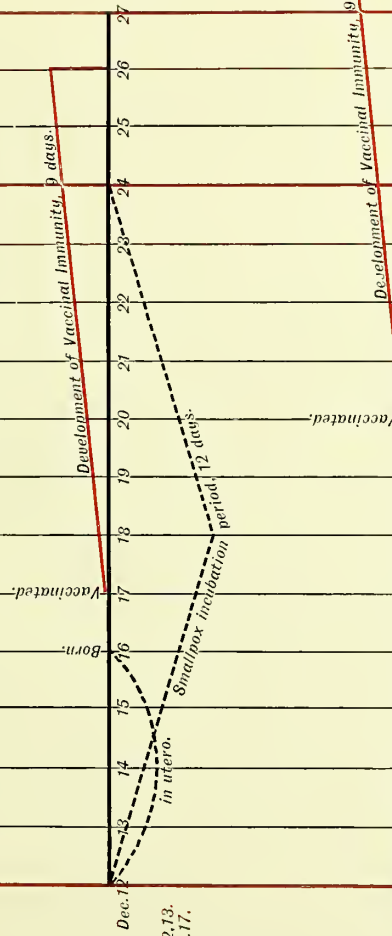


CASE 5.

Born, Dec. 16.
Mother's rash, Dec. 12-13.
Baby vaccinated, Dec. 17.
Infected in utero.

PLATE XXXII.

Mild.
Onset, Dec. 24.
Eruption, Dec. 27.
Papules more profuse
than in cases 3 & 4.
Extent of eruption
restricted, individual
papules large and
normal size.

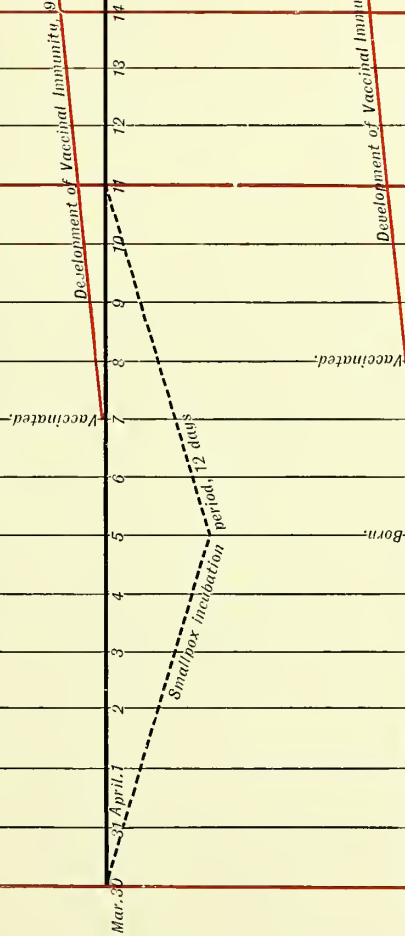


CASE 6.

Aged 4 months.
Infected, Mar. 30.
Vaccinated, April 7.

PLATE XXXIII.

Mild.
Onset, April 11.
Eruption, April 14.
Papules numerous on
head & extremities
& of full size.



CASE 7.

Born, Mar. 6.
Mother's rash, Feb. 28, Mar. 1.
Baby vaccinated, Mar. 9.
Infected in utero.

No PLATE AVAILABLE.

Severe.
Eruption, March 15.
Papules very num-
erous, eruption dis-
crete. Death ensued.



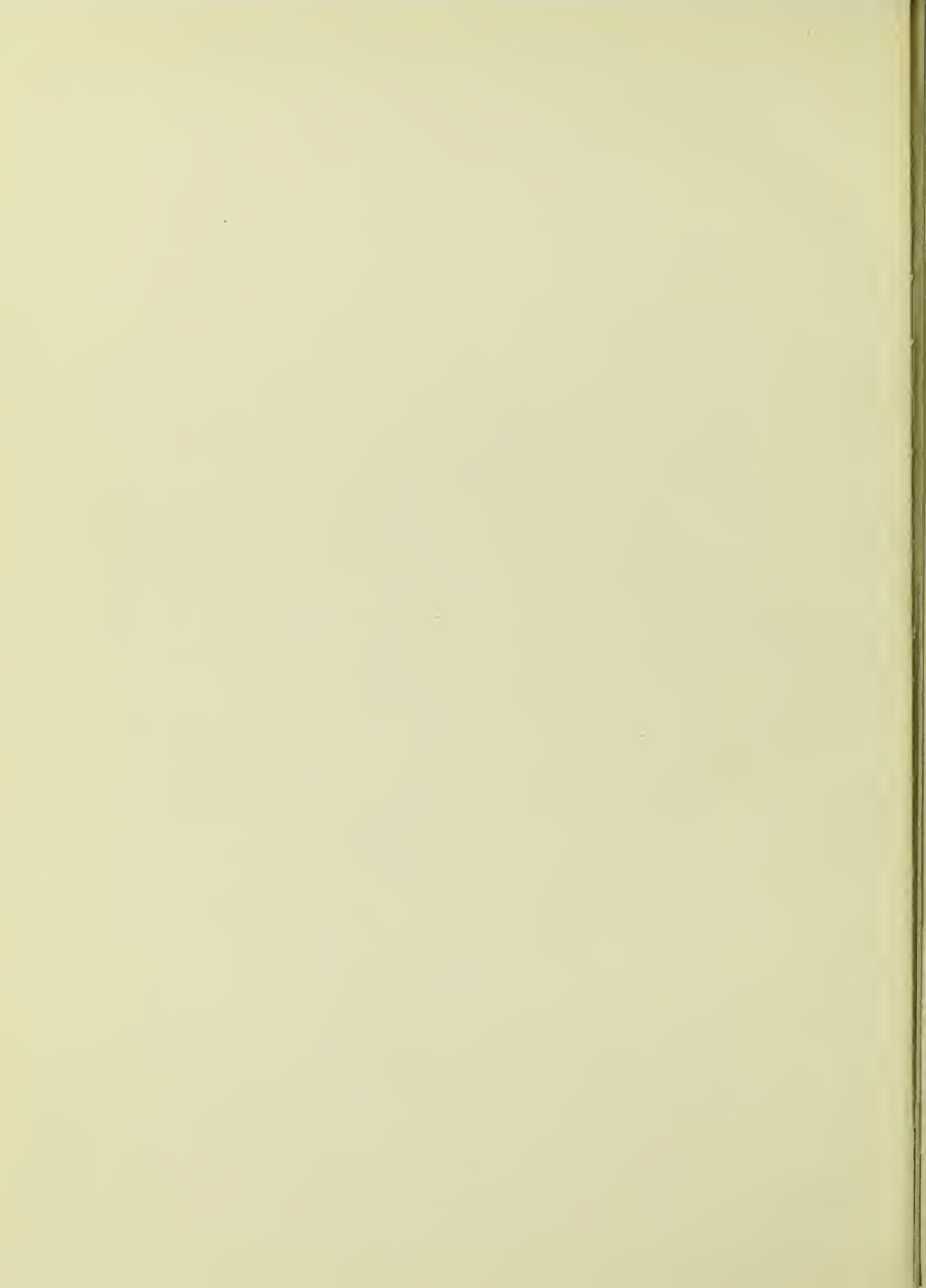


PLATE XVIII



CASE 1.—A CHILD SUCCESSFULLY VACCINATED ON THE DAY OF BIRTH AND NURSED BY ITS MOTHER, WHO HAD SMALL-POX, THROUGHOUT HER ILLNESS OF SIX WEEKS IN A SMALL-POX HOSPITAL

Child born January 15th, vaccinated successfully on January 16th. Mother developed small-pox rash on January 16th, and nursed her child in hospital until discharged. No development occurred in the child.

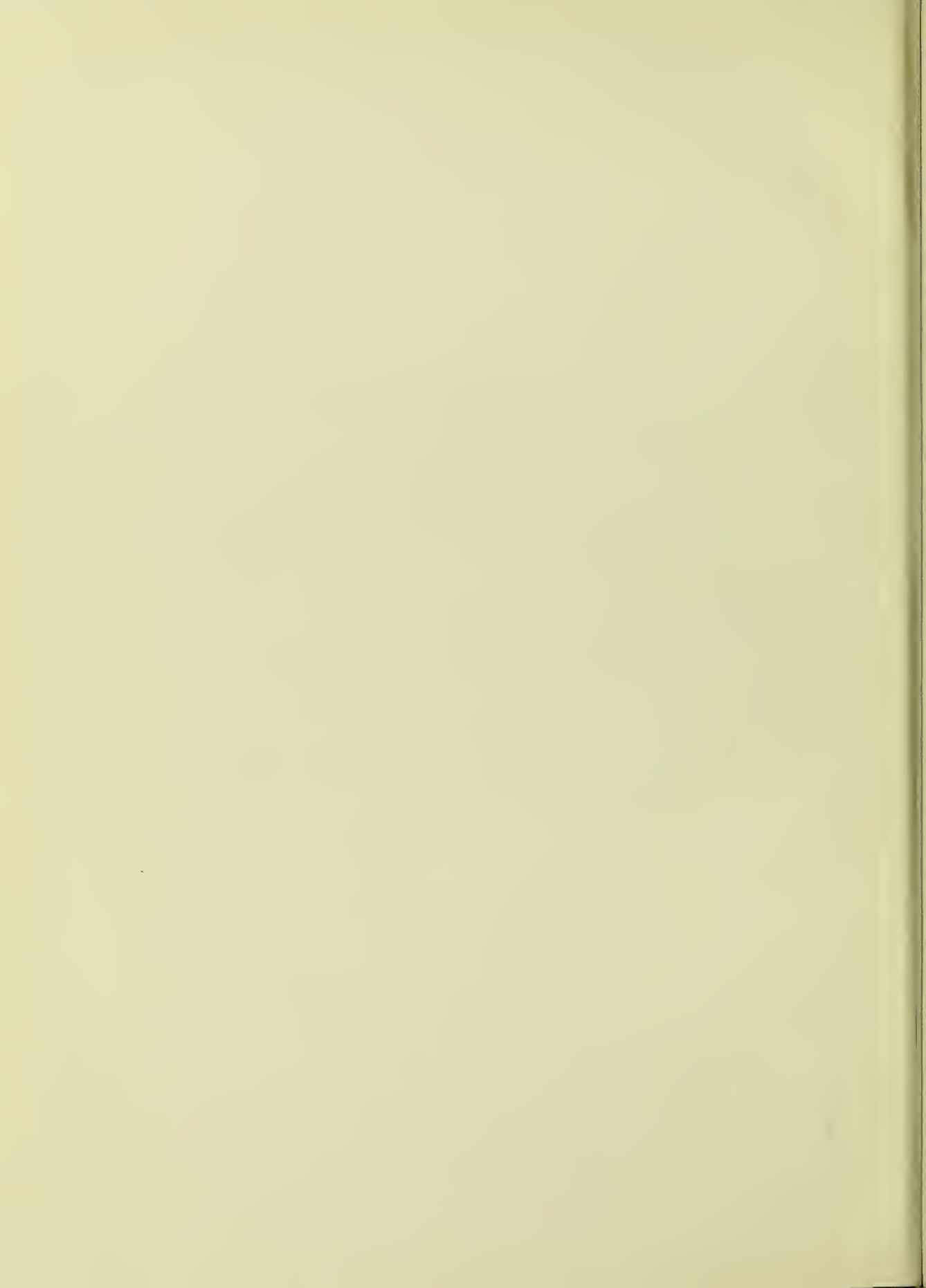


PLATE XIX

Small Pox



CASE 2.—MOTHER SUFFERING FROM SMALL-POX NURSING HER
SUCCESSFULLY VACCINATED BABY

Mother aged twenty-five years. Vaccinated in infancy. Baby born in hospital and successfully vaccinated on the following day. No signs or symptoms of small-pox appeared in the child, which was nursed by the mother throughout her own illness in hospital, and discharged after six weeks. (A) Infant's successful vaccination. Photo taken on the ninth day of the vaccination.

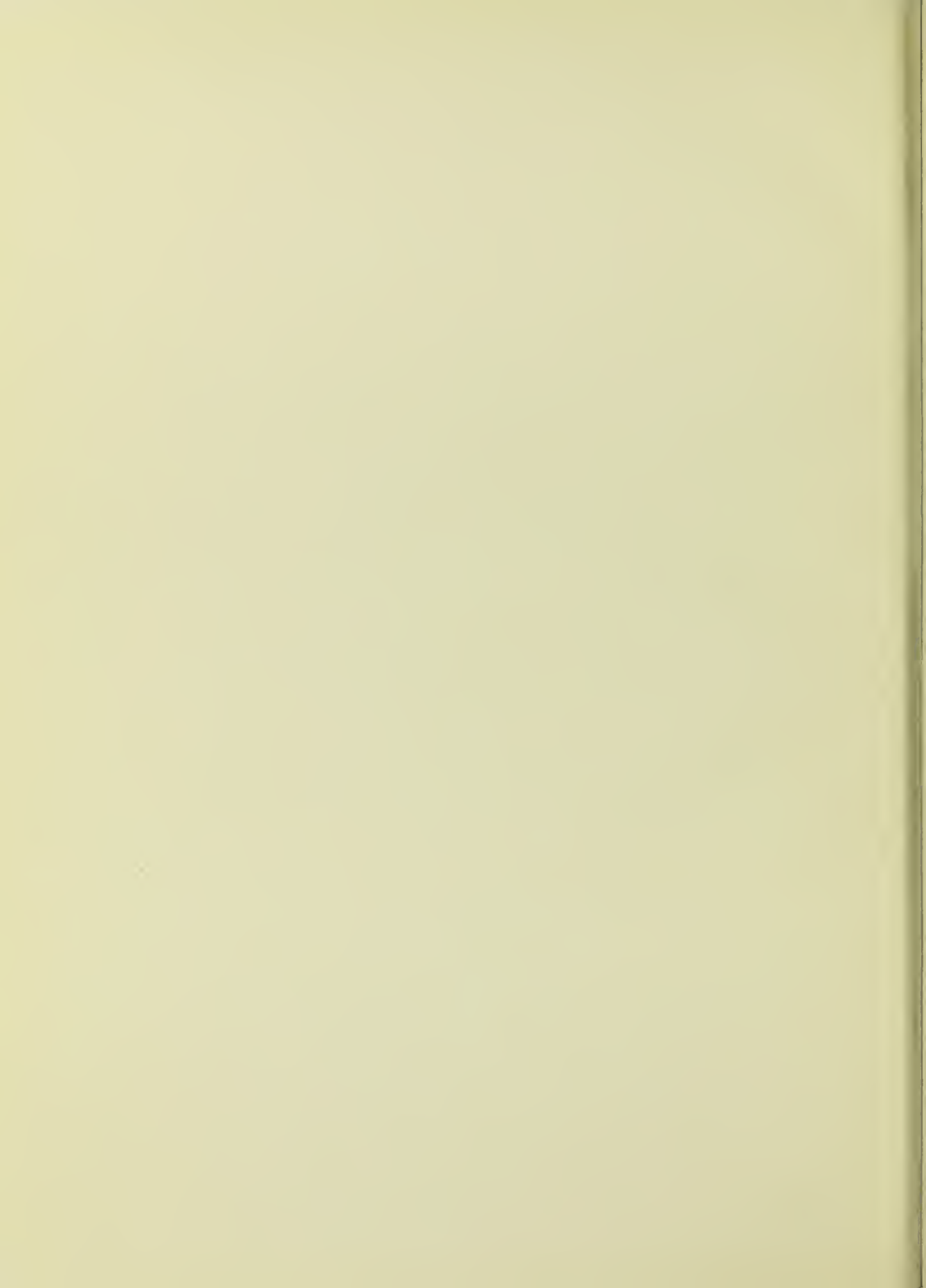


PLATE XX



CASE 3.—AN EXCEEDINGLY MILD AND MODIFIED ATTACK
OF SMALL-POX

Child born April 19th, vaccinated successfully April 22nd, three days after infection. Mother developed small-pox rash on April 19th, and nursed the child throughout her illness. The baby developed a small number (twenty) of small-pox papules scattered on its body. Photo taken on the third day of the rash.



PLATE XXI



CASE 4.—A VERY MILD AND MODIFIED CASE OF SMALL-POX

Child aged three months, was vaccinated successfully four days after infection with small-pox, i.e., eight days before onset. The child developed a very mild attack of small-pox: not more than eight or nine papules on the face, and about twenty on the body.



PLATE XXII



CASE 5.—ANOTHER CASE OF MILD SMALL-POX IN AN INFANT
SUCCESSFULLY VACCINATED BEFORE ONSET

Child aged fifteen days, born on December 16th, and successfully vaccinated five days after infection from the mother, whose rash appeared on December 12th. The child developed a mild attack of small-pox with sparse eruption. It will be noticed that the later the day of vaccination after infection, the more severe the character of the disease. Compare *Plates XX, XXI, and XXIII*. Photo taken on sixth day of the rash.

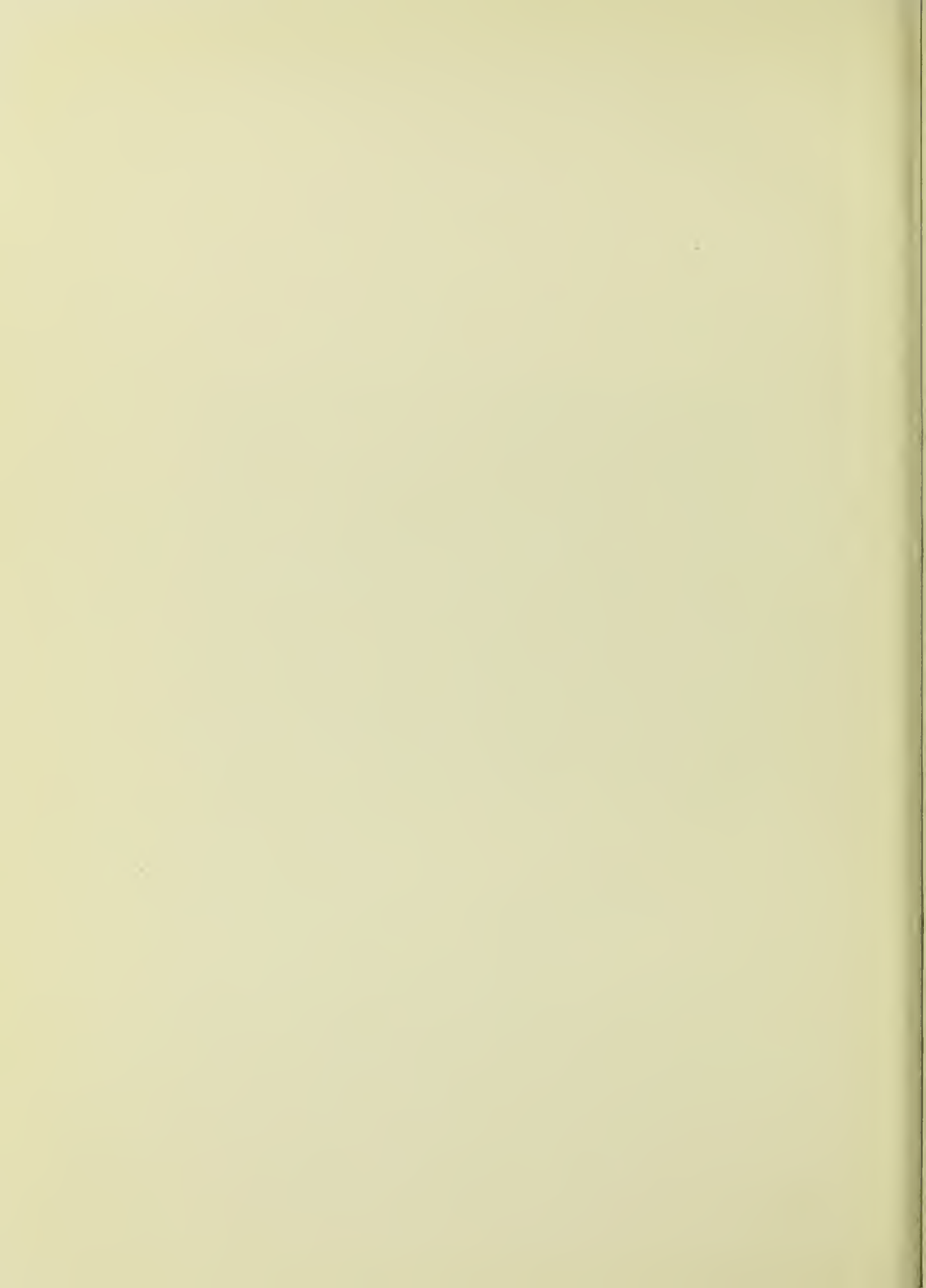
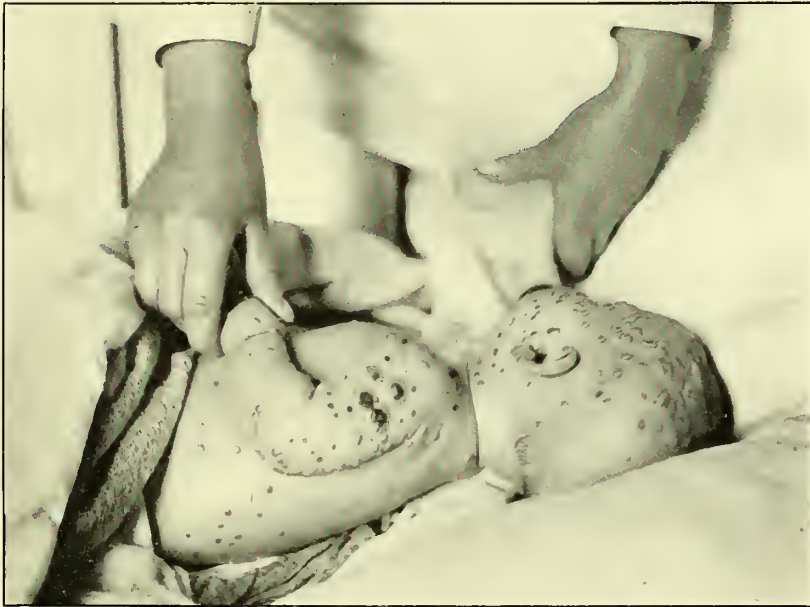


PLATE XXIII



CASE 6.—ANOTHER CHILD, SHOWING A MILD AND MODIFIED ATTACK OF SMALL-POX, AND VACCINATED FOUR DAYS BEFORE ONSET

Child aged four months, was successfully vaccinated eight days after infection with small-pox. The patient developed a modified attack of small-pox, but the eruption was much more numerous and pronounced, and papules of larger size, than in any of the previous cases. Photo taken on eighth day of the rash.

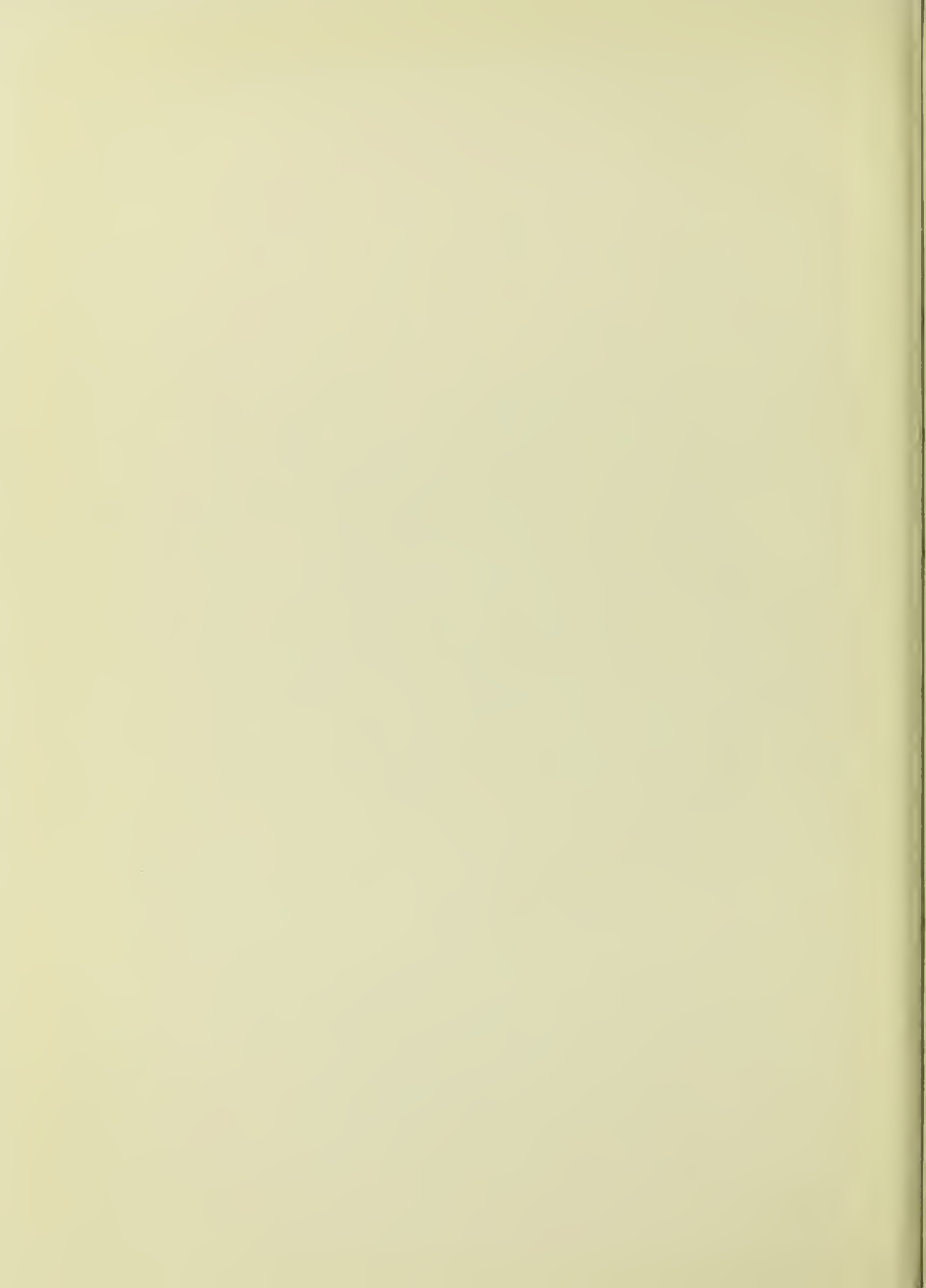


PLATE XXIV



A FATAL CASE OF SMALL-POX IN A CHILD

The child was aged four months, and had never been vaccinated. The distribution of the rash is well seen, and is chiefly confined to the head and extremities. The small-pox papules are well seen on the soles of the feet; the eruption is sparse on the trunk.

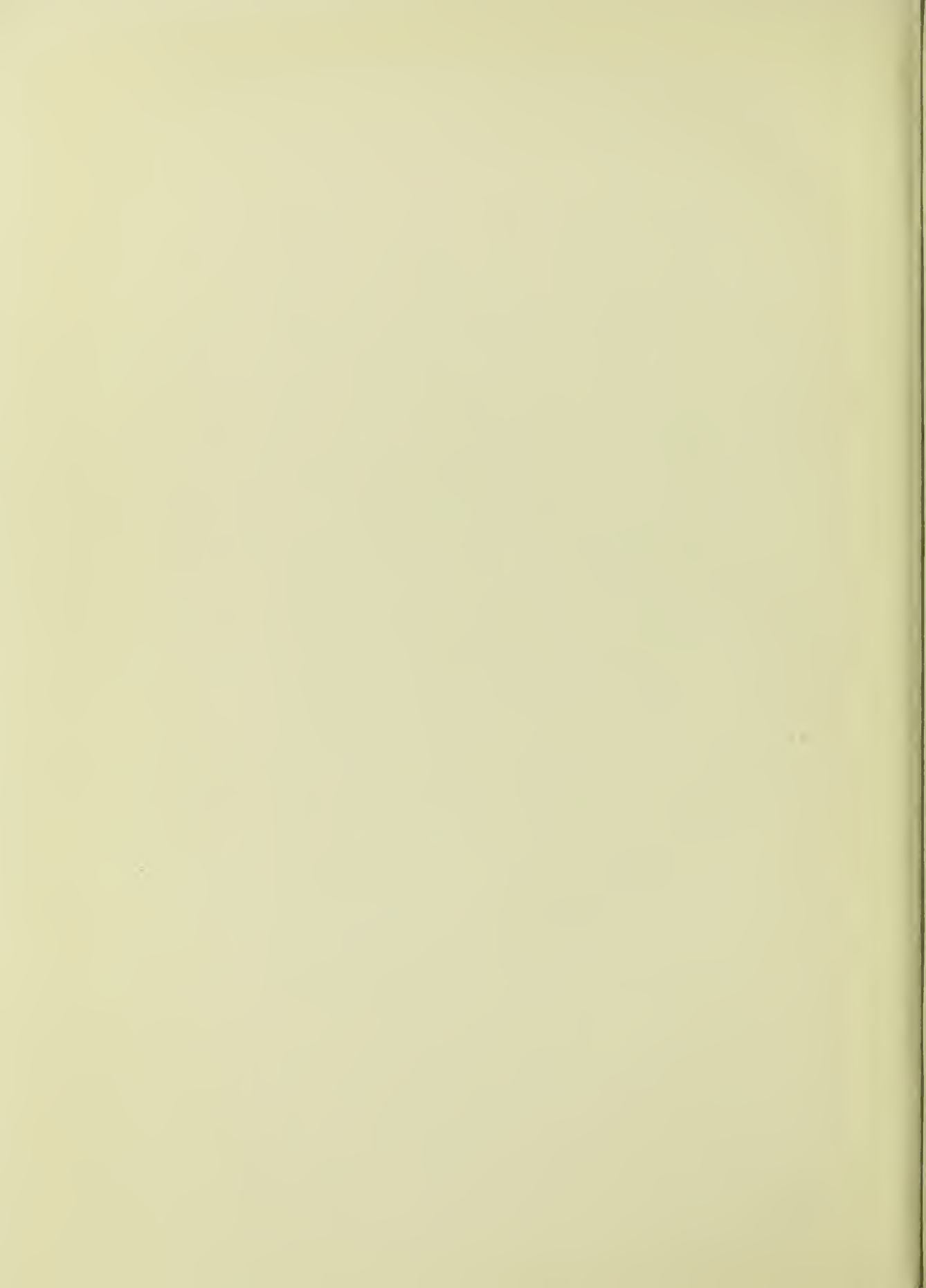
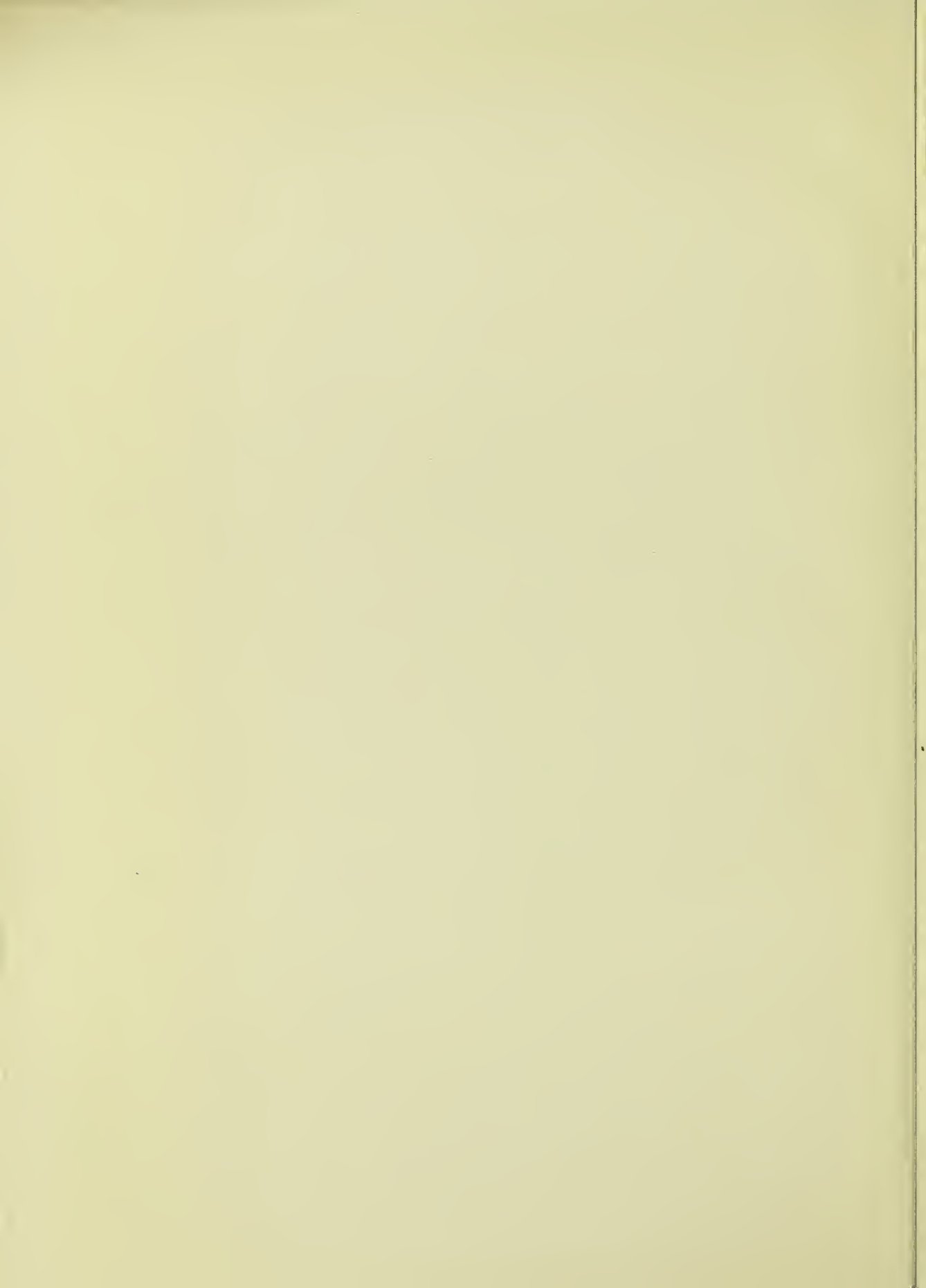


PLATE XXV



A FATAL CASE OF SMALL-POX IN A CHILD AGED TEN MONTHS

The child had never been vaccinated, and the rash is even more profuse than in *Plate XXIV*. Note the sparsity of eruption on the trunk.



CONCLUSIONS.

The following conclusions may be drawn from the series :—

Part I :—

- (a). That the case mortality in the natural disease, i.e., in the unvaccinated, which ranges from approximately 25 to 40 per cent, has been reduced by the power of vaccination to about 3 per cent in those who have been well vaccinated.
- (b). That in the unvaccinated, persons at the extremes of life, mainly children under 10 years of age and old people, are those who suffer most, the case mortality reaching as high as 50 per cent. In the previously vaccinated, no cases are recorded occurring under three years of age; under twenty years of age no deaths are recorded, but as age advances the vaccination gradually loses its protective and modifying power.
- (c). That even when, owing to age, and consequent gradual loss of vaccinal immunity, vaccination is unable to stop the development of the disease, it may modify the extent and character of the eruption to such a degree as to make it so exceedingly mild that in many instances the disease may be undetected.

Part II :—

- (d). That the scar-area of vaccination has an important bearing on the severity of the disease ; the larger the area, the milder the character of the disease.
- (e). That the vaccination scar-area gets larger as age advances until the 20-30 years age-period is reached ; it then gradually becomes smaller, in all probability owing to atrophy of the scar tissues.

Part III :—

- (f). That vaccination performed subsequently to infection with small-pox and up to the date of onset of symptoms will "take" and pass through its typical course.
- (g). That protection is afforded against small-pox by vaccination when performed within three days after infection, but this may not be absolute in cases vaccinated for the first time ; the course of the disease, however, will be exceedingly mild.
- (h). That there is abundant evidence of the value of vaccination in mitigating the severity of the disease when performed at any time after infection up to date of onset, and even afterwards.

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